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George H. Ashley, State Geologist.

GAS IN TIOGA COUNTY, PENNSYLVANIA

By

S. H. CATHCART and T. H. MYERS

Palmer No. 1 discovery well in Tioga Field.
Kemp No. 1 in distance. Typical field terrane.

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GAS IN TIOGA COUNTY, PENNSYLVANIA

By S. H. Cathcart* and T. H. Myers**

RESUME OF GAS OCCURRENCES IN THE ORISKANY SAND

Tioga became a gas-producing county in September 1930, when Palmer #1 well of the Allegheny Gas Company came in wild. This well, located in a domed area on the Sabinsville anticline, yielded 22 million cubic feet a day at 1665 pounds rock pressure from the Oriskany sand at 4,006 feet depth. Discovery here followed discovery in the Wayne-Dundee Field, Schuyler County, New York where the Belmont Quadrangle Drilling Company brought in a 6 million cubic foot well in the Oriskany sand March 1, 1930#. The finding of such large volume, high pressure wells within easy access of populous industrial localities where gas might be expected to command a substantially high price aroused considerable interest. In the leasing campaign that followed, millions of acres of land were involved. Activity centered in south-central New York and adjacent Pennsylvania but extended in New York from the Adirondacks on the north to the Catskills on the east, and in Pennsylvania from Susquehanna County on the east to McKean County on the west, in Lycoming and Sullivan counties extending south to the Allegheny Front.

The extent of developments in the Oriskany sand, their relation to structure and to oil and gas fields in the "shallow" sands, is shown on Figure 1. Pertinent record of the scattered wells will be found under List of Wells at the end of the paper.

In New York State three fields have been discovered. They are the Wayne-Dundee in Schuyler County, the Allentown in Allegany County, and the Greenwood in Steuben County. Two fields have been proven in Pennsylvania - the Tioga, Tioga County, and the Hebron, Potter County. In addition three successful wells have been drilled at three separate localities in Potter County, any one or all of which may develop into fields. They are the Moran well on the Smethport anticline, the Estes on Hebron anticline 6 miles northeast of Hebron field, and the Emporium Lumber Company well on Marshlands anticline. Eight other domes in Pennsylvania were tested by 11 wells without success, and 2 wells are now drilling on another dome.

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#See New York State Museum, Circular 7, February 1932.

A brief description of the fields other than Tioga Field, which will be described in some detail, follows.

The Wayne-Dundee Field*, which is located on a dome on the Fir Tree anticline, has more than 100 producing wells. Initial open flow ranges from 1 to 10 million and averages about 6 million cubic feet a day. The rock pressure is about 700 - 750 pounds and wells are 1,700 - 2,000 feet deep.

While no structural division is definitely recognized, the field is divided into two areas, the Wayne and the Dundee, on the basis of product. The Dundee area produces "sour" (sulphurous) gas, the Wayne produces sweet gas. After more than two years of producing, sour gas is beginning to appear in the Wayne area.

The proven area of the field is about 6,000 acres; the estimated potential yield about 17¼ billion cubic feet, 4¼ for the Wayne and 13 for the Dundee area.

In the Allentown Field six wells have been completed in the Oriskany. Two tests are dry, four show gas and three of the four also show a little very light oil and some salt water. One test is now being drilled.

Only one of the four wells that showed gas is a commercial well. It gaged 1½ million cubic feet initial open flow at 1320 pounds rock pressure and is estimated to be capable of producing 3 to 5 barrels of oil daily.

The average thickness of the Oriskany is 10 feet and the depth of wells approximately 3,000 feet.

Oil is known to occur in the Oriskany at only two other localities, namely, at Cambridge, Ohio and on Knapp Creek dome, Bradford-Allegany field, Pennsylvania and New York.

Two commercial wells have been completed in the Oriskany sand in the Greenwood Field. One on the Warriner farm, completed October 20, 1932, had an initial open flow of 1,000,000 cubic feet and rock pressure of 1545 pounds. It encountered considerable salt water but produced for several months without showing any decrease in gas volume.

A second test on the Lewis Weber lease completed, March 1, 1933, had an open flow of 13,500,000 cubic feet. Salt water was encountered in this well but not in as large volume as in the discovery well.

A third test is now being drilled some distance east of the Webber well.

In Hebron field** there are now (Feb. 2, 1934) 14 producing wells, 2

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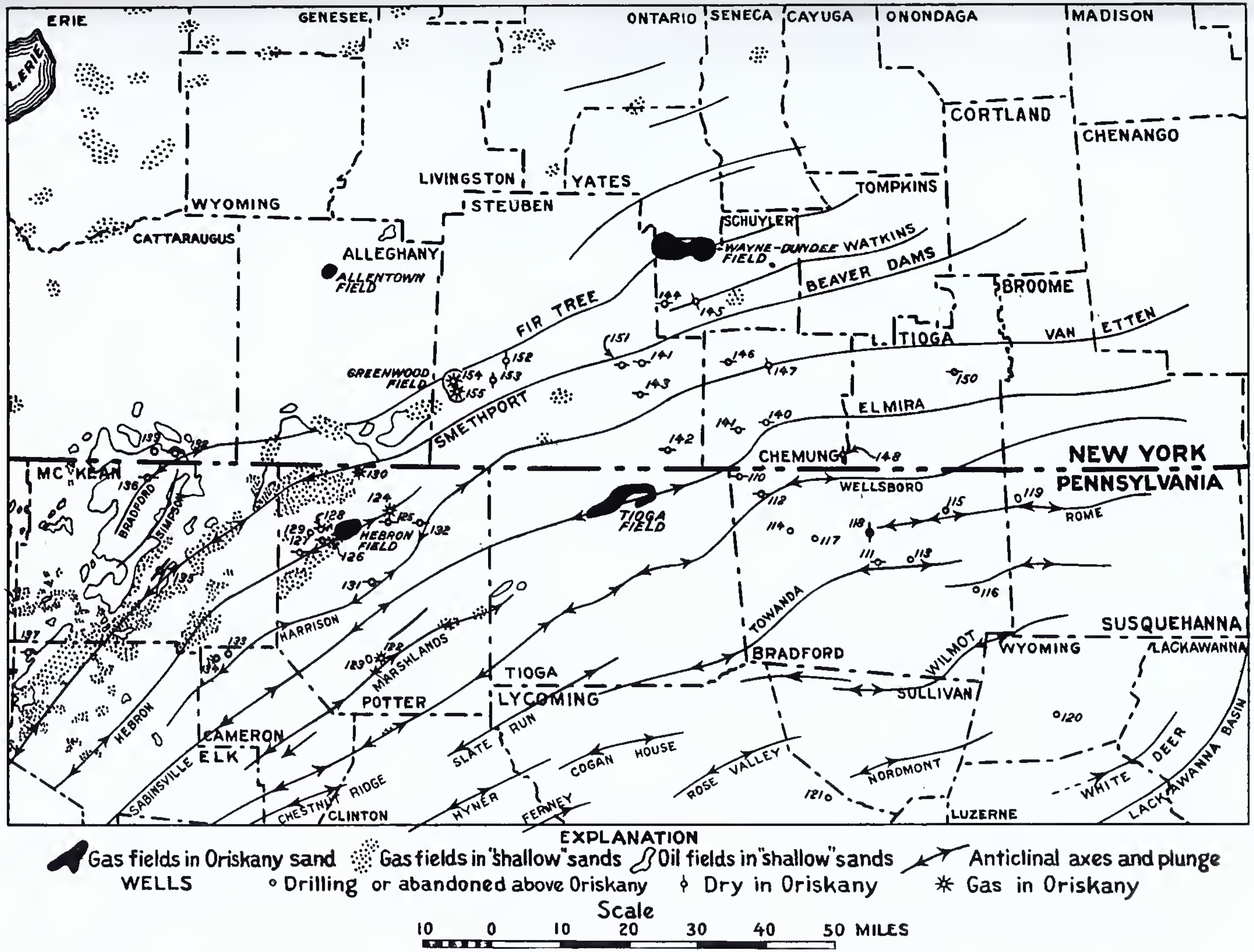
* New York State Museum, Circular 7, February 1932.

** Described in Pennsylvania Geol. Survey, Mim. Bull. No. 106, Feb. 1, 1934.



ORISKANY SAND DEVELOPMENTS IN NORTHERN PENNSYLVANIA AND SOUTH-CENTRAL NEW YORK.

dry holes, and 7 drilling wells. Three wells have been abandoned above the sand and two are shut down. The initial open flow of wells ranges between 1 and 33 million cubic feet a day, averages about 13 million and totals almost 184 million cubic feet. Rock pressure averages about 2100 pounds per square inch. The gas is sweet and has a B.t.u. value of 1020. Wells start near the top of the Chemung and are about 5,000 feet deep. The proven area is 2½ miles long and 1½ miles wide; the effective closure is about 200 feet.

Six miles southwest of the proven area, 4 wells have found the Oriskany sand to be absent on the plunge and on the north flank of the structure. Six miles northeast of the proven area a dry hole and a 13 million foot well are located within 1,800 feet of each other. It remains to be proven how far southwest of the present productive area the Oriskany sand extends and whether the well 6 miles northeast represents a separate pool or a continuation of Hebron Field in that direction. The south flank of Hebron dome is definitely faulted just south of the axis, and the two wells 6 miles to the northeast reveal the presence of faulting at that locality. At Hebron Field one well has found gas on a closure south of the fault, more than 250 feet below effective closure on Hebron anticline.

The Moran well (130) is located just east of Shinglehouse "shallow" gas field on the Smethport anticline. The well started in Catskill red beds and found the Oriskany at 4,875 feet. It is said detailed geologic work shows that the well is located on a closed structure. This closure was not apparent to us on reconnaissance examination. The well had an estimated initial volume of 8 million cubic feet under rock pressure of 1950 pounds and flowed much salt water along with the gas. Further testing is needed to prove the value of this discovery.

The Emporium Lumber Co. well (122) is in a domed area on the Marshlands anticline. It started in Catskill red beds and found the Oriskany at 6,280 feet. The initial volume of the well was 85,000 cubic feet. A second test is now being drilled on this structure.

The location of "wildcat" wells that failed in the Oriskany is shown on Fig. 1 and a partial record of each is given under List of Wells.

GEOLOGY OF TIOGA COUNTY

Tioga is one of the north tier of counties just east of midway the length of Pennsylvania. Its area is about 1125 square miles. Physiographically it is a part of the Allegheny Plateau Province, its southern boundary extending to within 15 miles of the Allegheny Front. The surface of the county, however, bears no resemblance to a plain. Strong folds traverse the region in a northeasterly direction and erosion of the folded rocks has resulted in the development of rolling valley lands in the anticlinal areas and rugged mountains in the synclinal areas. The maximum relief in the valley lands is about 500 - 600 feet; in the mountainous sections 1200 - 1500 feet.* Practically all of the mountainous area is densely wooded.

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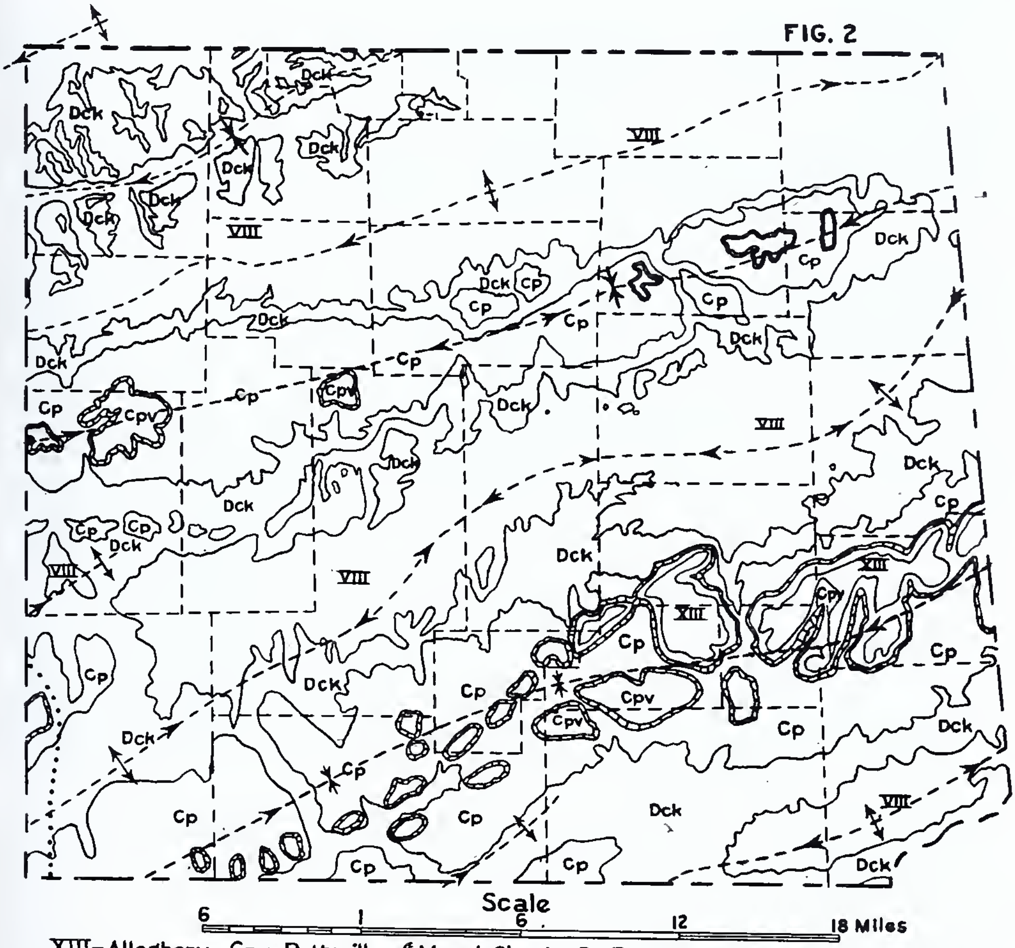
* See U.S.G.S. topographic sheets for Gaines, Elkland, Tioga, and Blossburg quadrangles.

Stratigraphy

All the rocks that are exposed, or that are known to occur within 10,000 feet of the surface in Tioga County, are of sedimentary origin. They are chiefly marine, but include fluviatile and glacial deposits.

Excluding the glacial deposits the total thickness of sediments exposed is about 4,000 feet. These rocks range in age from Devonian to Pennsylvanian. Most of them are shale and sandstone, but conglomeratic sandstone is of quite common occurrence, limestone is present, and there are some beds of coal, clay, and iron ore.

FIG. 2



XIII=Allegheny Cpv=Pottsville ƒ=Mauch Chunk Cp=Pocono Dck=Catskill VIII=Chemung
········ South limit of glaciation

DISTRIBUTION OF GEOLOGIC FORMATIONS

The geologic column as known is as follows:

Rocks exposed in Tioga County

	Feet
Quaternary	
Recent	
Alluvium	
Pleistocene	
Glacial deposits	
Unconformity	
Carboniferous	
Pennsylvanian	
Allegheny group	*70+
Pottsville group	181±
Unconformity	
Mississippian	
Mauch Chunk shale	0-40
Pocono ? ("Oswayo") group	1,100±
Devonian	
Catskill ? ("Cattaraugus") group	500±
Chemung group	2,000±
Portage group	20±

Rocks not exposed

	Feet **	Feet #
Portage group	1,742	1,400±
Genesee black shale	159	?
Tully limestone	82	80±
Hamilton group	716	1,000±
Marcellus black shale	206	500±
Onondaga limestone	17	40±
Oriskany sandstone	50	50±
Helderberg group	224	275±
Tonoloway limestone	57	
Silurian		
Salina group	163	2,700±
Syracuse salt	2,106	
Vernon shale	618+	
Bottom of well estimated distance to Medina 650 - 850 feet		
Clinton group		600-700±
Medina group		2,000±

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*U.S.G.S. Folios 92 and 93.

**From detailed log of Shoemaker #1 well, Lawrence Township, Bull. 102B, Pennsylvania Geol. Survey, 1932.

#Generalized section for the region, Bull. 102B., Penna. Geol. Survey, 1932.

The distribution of the rocks that appear at the surface is shown by Figure 2 on which appears the surface trace of anticlinal and synclinal axes. It should be noted that the younger rocks have been preserved in the synclinal, now the mountainous areas and that the older rocks are exposed in the anticlinal or valley areas.

Rocks Exposed*

Portage group. In Farmington Township where streams have cut deeply into the flanks of the Tioga dome they expose the upper few feet of the Portage group. The rocks are gray shale and physically are so like the shales of the Chemung that they can be separated only paleontologically.

Chemung group. The name Chemung is here used to designate approximately 2,000 feet of alternating shales, sandstones and thin, impure limestones that underlie the red beds of the Catskill formation. These are the oldest rock that are widely exposed in Tioga County.

The series consists chiefly of limy and shaly sandstones alternating with thick beds of soft shale and occasional thin beds of impure limestone. Gray, greenish-gray, and buff are the chief colors of both the sandstones and the shales. The limy sandstone is a somewhat coarse, friable rock that grades into gray, somewhat flaggy sandstone or into impure limestone. The limestone is commonly dark bluish gray to almost black. It occurs in beds from a few inches to several feet thick and often is rich in fossils. The shales are dominantly sandy and grade into shaly sandstones. Although from surface exposures it would seem that sandstones in beds of a few inches to a few feet thick make up most of the thickness of the Chemung, well records and carefully measured sections indicate that shales are more abundant.

Chemung rocks appear at the surface in three rather well defined belts that correspond to the structurally high anticlinal areas.

In western Pennsylvania the Chemung group is of great economic importance as in it occur important oil- and gas-producing sands. In Tioga County it has yielded oil at Gaines and at scattered localities small amounts of gas. The formation includes iron ore (hematite) beds locally that once were mined, but which have no present value.

Catskill-Pocono group. What probably corresponds to the Catskill red beds and the Pocono sandstone in adjacent regions has in Tioga County been mapped** under the names Oswayo and Cattaraugus formations. Plant, invertebrate, and fish remains indicate that the formations are chiefly of continental origin.

In western Pennsylvania the Catskill formation includes the famous Venango and other oil and gas sands and small quantities of gas have been obtained from the Catskill in Tioga County.

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*For more detailed description of the stratigraphy and general geology of the county see (1) vol. G, Second Pennsylvania Geological Survey; (2) U.S.G.S. Folios Nos. 92 and 93; (3) Pennsylvania Geol. Survey, Bull. 102-B.

** U.S.G.S. Folios 92 and 93.

The Catskill ? ("Cattaraugus") group consists of a succession of red shale and brown sandstone interspersed at intervals with gray and greenish shales and sandstones. Red beds may constitute 50 to 75 per cent of the group, which is about 500 feet thick. Of the gray and green materials the sandstones, being hardest, stand out as ledges and are therefore most conspicuous. These sandstones are invariably cross-bedded and the individual layers are often thin, perfect plates.

The limits of the formation are places so as to include in it the dominately red rocks of this part of the section. The Catskill is widely distributed and is readily recognized by its prevailing red color.

The Pocono ? ("Oswayo") group consists of a thick series of gray and green sandstones and shales with occasional thin beds or lenses of red shale. Its total thickness is about 1,000 feet. Green and gray sandstones predominate and because of their hardness frequently stand out on the hillsides as distinct shelves. They are invariably cross-bedded and resemble very closely the sandstones of the Catskill group, above which they occur.

The Pocono grades into the red Mauch Chunk above and into the red Catskill below it; its upper and lower limits therefore are determined by the beginning of dominant red beds.

Mauch Chunk group. At Mauch Chunk this group is about 2,000 feet thick and consists chiefly of red shale and sandstone. How great a thickness was deposited in Tioga County is not known for, following its deposition, this and adjacent areas were elevated above sea level and the Mauch Chunk was eroded. Locally all the Mauch Chunk was removed and elsewhere less than 50 feet, perhaps, was preserved. Pottsville rocks were deposited on this eroded surface.

Where known in Tioga County the Mauch Chunk consists of red and green shales with green and buff sandstone; locally it carries fire clay and iron ore.

Pottsville group. No complete section of the Pottsville in Tioga County is recorded as such. In northern Pennsylvania where detailed studies have been made, only part of the Pottsville is present; in the Blossburg basin where a complete section is present careful studies have not been made. Our best guide is a section published by the First Geological Survey of Pennsylvania. This we interpret as follows:

	Feet
Homewood sandstone	27
Mercer shale and coals . .	84
Connoquenessing sandstone .	25
Sharon shale and coals . . .	18
Sharon conglomerate	27
	181

While valueless so far as establishing an average is concerned it serves to show that the Pottsville probably is present in its five-fold form. The First Survey considered that the Blossburg coal bed, which falls in the interval named Mercer above, was equivalent to the Lower Kittanning coal (Allegheny age) of western Pennsylvania. David White, however, on evidence furnished by fossil plants, showed the Blossburg coal to be equivalent to the Mercer, and the Seymour coal, which overlies the horizon that is here called Homewood, to be equivalent to the Brookville coal of western Pennsylvania. In our interpretation the First Survey's section is recast to conform with White's later correlations.

Allegheny group. Detailed geologic studies have shown pretty definitely that this formation is not present in the northern half of the county. In the Pine Creek syncline where Pottsville rocks are recognized and where remnants of the Allegheny might also be expected to occur, apparently all of the Allegheny group has been removed by erosion. Information for the southern half of the county is meager but we do know that the Seymour or Cushing coal that occurs locally in the Blossburg syncline is equivalent to the Brookville coal of lower Allegheny age. At Morris Run about 70 feet of sandstone, shale, coal, and fire clay are assignable to the Allegheny but we do not know that this is the maximum thickness preserved.

Glacial deposits. Glacial or glaciofluviatile deposits of Wisconsin and Jerseyan age occur throughout all except the extreme southwest corner of the county. The drift is thickest in the valley bottoms where it may exceed 100 feet. Throughout considerable areas it is only a few feet thick or is absent.

Alluvium includes chiefly gravels, sand, silt and clay deposits in or near the present stream channels, but also includes some materials deposited in lakes, since drained.

Rocks not Exposed

The lithology of the unexposed rocks is best described by quoting from the geologic log of the Shoemaker well, the deepest well drilled in this region.

Detailed log of J. E. Shoemaker No. 1 well,*
of Lycoming Natural Gas Corporation, Lawrence Township, Tioga County, Pa.

Elevation, top of well, 1474 feet.

Description of Strata	Depth Top	Bottom
CHEMUNG GROUP		
Soil	0	24
Very fine-grained, bluish to greenish gray sandstone with minute muscovite scales	24	85
Bluish to greenish gray sandy shale	85	174

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*Based upon an examination of a complete set of cuttings. By. C. R. Fettke, for the Pennsylvania Geol. Survey.

Very fine-grained, light greenish-gray sandstone, slightly calcareous	174	186
Greenish-gray sandy shale - few fossils	186	321
Very fine-grained, dark grayish brown sandstone	321	327
Greenish sandy shale	327	333
Brownish gray sandy shale	333	350
Greenish gray sandy shale	350	372
Very fine-grained, greenish gray sandstone	372	378
Greenish gray sandy shale - in part slightly calcareous and containing an occasional brachiopod	378	734
Very fine-grained dark brownish gray sandstone - somewhat calcareous	734	741
Interbedded dark gray shale and greenish gray sandy shale	741	795
Very fine-grained dark greenish gray sandstone	795	801
Greenish to dark greenish gray sandy shale with some interbedded dark gray shale	801	897
Dark gray shale	897	954
Dark greenish gray sandy shale with some interbedded dark gray shale	954	1008

PORTAGE GROUP

(Contact between Chemung and Portage placed here tentatively)

Very fine-grained, dark greenish gray sandstone	1008	1014
Greenish gray sandy shale	1014	1020
Very fine-grained, greenish gray sandstone	1020	1026
Dark gray shale with some interbedded greenish gray shale	1026	1074
Dark greenish gray sandy shale with some interbedded dark gray shale	1074	1128
Dark gray shale with a little interbedded dark greenish gray sandy shale	1128	1243
Dark greenish gray sandy shale with some interbedded dark gray shale	1243	1359
Very dark gray, almost black, shale with some interbedded dark greenish gray sandy shale	1359	1373
Dark greenish gray sandy shale with some interbedded very dark gray shale	1373	1410
Dark greenish gray sandy shale	1410	1496
Dark gray shale with some interbedded dark greenish gray sandy shale	1496	1593
Interbedded dark gray sandy shale and shale	1593	1944
Grayish black shale with some interbedded very dark gray shale	1944	1968
Very dark gray shale with some interbedded grayish black shale	1968	2011
Very dark brownish gray sandy shale with some interbedded very dark gray shale	2011	2053
Very fine-grained, very dark brownish gray sandstone - slightly calcareous	2053	2060
Interbedded very dark brownish gray slightly calcareous sandy shale and very dark gray shale	2060	2088
Interbedded dark gray sandy shale and shale - slightly calcareous	2088	2455
Very dark gray shale	2455	2495
Dark gray shale with some interbedded gray sandy shale	2495	2532
Dark brownish gray sandy shale with some interbedded dark gray shale	2532	2612
Gray to dark gray shale, sandy in upper part	2612	2664
Gray to dark gray shale, somewhat calcareous	2664	2701
Very fine-grained dark gray calcareous sandstone	2701	2708
Dark gray shale - somewhat calcareous	2708	2728
Gray to dark gray calcareous shale	2728	2750

GENESEE BLACK SHALE

Grayish black shale - very slightly calcareous	2750	2909

TULLY LIMESTONE

Dark brownish gray argillaceous dense limestone	2909	2959
Dark gray shale - somewhat calcareous	2959	2978
Very dark brownish gray argillaceous dense limestone	2978	2991

HAMILTON GROUP

Dark gray shale - somewhat calcareous	2991	3014
Dark gray shale - slightly calcareous	3014	3038
Dark gray very calcareous shale	3038	3105
Very dark gray shale - slightly calcareous	3105	3156
Black calcareous shale	3156	3170
Very dark gray calcareous shale	3170	3200
Very dark gray shale - slightly calcareous	3200	3345
Very dark gray calcareous shale	3345	3382
Very dark gray, very calcareous shale	3382	3463

Horizon of STAFFORD LIMESTONE
(Probably in lower part of above shale)

Very dark gray calcareous shale	3463	3497
Grayish black shale - somewhat calcareous	3497	3505
Very dark gray calcareous shale	3505	3520
Grayish black shale - slightly calcareous	3520	3592
Very dark gray shale - slightly calcareous	3592	3608
Grayish black very calcareous shale	3608	3707

MARCELLUS BLACK SHALE

Black calcareous shale	3707	3913

ONONDAGA LIMESTONE

Very fine, dense gray to dark gray limestone	3913	3930

ORISKANY SANDSTONE

Medium-grained light brownish gray sandstone - somewhat calcareous	3930	3968
Medium-grained dark brownish gray calcareous sandstone	3968	3980

HELDERBERG GROUP

Very fine, crystalline, dark brownish gray fossiliferous limestone - somewhat siliceous and cherty	3980	4075
Very fine, crystalline, dark brownish gray sandy limestone - also contains some dark gray chert	4075	4080
Very fine, crystalline, brownish gray limestone - contains a little light gray chert	4080	4097
Very fine, dense, dark brownish gray, argillaceous magnesian limestone	4097	4123
Very fine, dense, dark brownish gray, argillaceous limestone	4123	4147
Very fine, dense, dark brownish gray, argillaceous magnesian limestone	4147	4168
Very fine, crystalline, light gray, siliceous magnesian limestone	4168	4178
Very fine, crystalline, dark gray to brownish gray argillaceous magnesian limestone	4178	4204

TONOLOWAY LIMESTONE

(Probably contains horizons of Lower Manlius, Cobleskill, and Bertie.)

Veryfine, dense, dark gray to brownish gray argillaceous limestone with abundant crinoid stems near top	4204	4261

SALINA GROUP

Camillus Formation.

Very fine, crystalline, light gray anhydrite	4261	4289
Very dark gray shale - somewhat calcareous	4289	4302
Very fine, crystalline, light gray anhydrite	4302	4310
Very dark gray shale - slightly calcareous	4310	4328
Very fine, crystalline, light gray anhydrite	4328	4335
Very fine, dense, brownish gray argillaceous magnesian limestone	4335	4341
Very dark gray shale - in part somewhat calcareous	4341	4394
Very fine, crystalline, brownish gray anhydrite - somewhat calcareous	4394	4399
Brownish gray calcareous shale - contains some anhydrite	4399	4424
Coarse, crystalline, grayish white salt with a little interbedded light gray shale	4424	4460
Light gray to brownish gray shale - slightly calcareous	4460	4486
Coarse, crystalline, grayish white salt with a little interbedded light gray shale	4486	4527
Light gray shale - slightly calcareous	4527	4533
Coarse, crystalline, grayish white salt with a little interbedded light gray shale	4533	4742
Light brownish gray shale - somewhat calcareous	4742	4748
Coarse, crystalline, grayish white salt with a little interbedded light gray shale	4748	4768
Gray shale - slightly calcareous	4768	4790
Coarse, crystalline, grayish white salt with a little interbedded light gray shale - in part calcareous	4790	4917
Light gray shale - somewhat calcareous, with some interbedded salt	4917	4992
Coarse, crystalline, grayish white salt with some interbedded light gray shale - somewhat calcareous	4992	5011
Light gray shale - somewhat calcareous	5011	5025
Coarse, crystalline, grayish white salt with some interbedded light gray to gray shale - somewhat calcareous	5025	5080
Gray calcareous shale	5080	5092
Coarse, crystalline, grayish white salt	5092	5098
Gray shale - somewhat calcareous	5098	5104
Coarse, crystalline, grayish white salt with some interbedded light gray shale - somewhat calcareous	5104	5120
Light gray shale - slightly calcareous	5120	5126
Coarse, crystalline, grayish white salt	5126	5132
Light gray to brownish gray shale - somewhat calcareous	5132	5158
Coarse, crystalline, grayish white salt	5158	5165
Gray to dark gray calcareous shale with some interbedded anhydrite in upper part and salt in lower part	5165	5349
Coarse, crystalline, grayish white salt with a little interbedded gray shale - somewhat calcareous	5349	5459
Gray, very calcareous shale containing a little anhydrite	5459	5465

Very fine, dense, dark brownish gray argillaceous magnesian limestone containing a little anhydrite	5465	5527
Coarse, crystalline, grayish white salt	5527	5552
Very fine, dense, dark brownish gray argillaceous magnesian limestone	5552	5559
Very dark gray calcareous shale	5559	5577
Very fine, dense, dark brownish gray argillaceous magnesian limestone containing a little anhydrite	5577	5601
Coarse, crystalline, grayish white salt with a little interbedded brownish to dark brownish gray shale - somewhat calcareous	5601	5645
Very fine, light gray argillaceous anhydrite - calcareous	5645	5658
Light gray to brownish gray shale - somewhat calcareous, with some interbedded anhydrite	5658	5690
Very fine, light brownish gray anhydrite - somewhat calcareous	5690	5695
Light gray to gray shale - somewhat calcareous containing some anhydrite in upper part	5695	5782
Very fine crystalline, dark brownish gray argillaceous magnesian limestone	5782	5851
Light brownish gray calcareous shale - contains some anhydrite	5851	5863
Very fine, dense, light to dark brownish gray argillaceous limestone	5863	5869
Light to dark gray calcareous shale - contains a little anhydrite	5869	6041
Coarse, crystalline, grayish white salt with some interbedded dark gray shale - somewhat calcareous	6041	6055
Gray to dark gray shale - somewhat calcareous	6055	6068
Very fine, dense, dark brownish gray argillaceous magnesian limestone	6068	6087
Very fine, dense, very dark brownish gray argillaceous limestone	6087	6120
Coarse, crystalline, grayish white salt with some interbedded gray shale - somewhat calcareous	6120	6134
Brownish gray very calcareous shale	6134	6147
Coarse, crystalline, grayish white salt with a little interbedded dark gray shale - somewhat calcareous	6147	6166
Very fine, dense, very dark brownish gray argillaceous magnesian limestone	6166	6190
Very fine, dense, very dark brownish gray argillaceous dolomite	6190	6196
Gray calcareous shale	6196	6233
Coarse, crystalline, grayish white salt	6233	6327
Very fine, dense, very dark brownish gray argillaceous limestone	6327	6335
Light gray very calcareous shale	6335	6342
Coarse, crystalline, grayish white salt	6342	6349
Gray shale - somewhat calcareous	6349	6358
Coarse, crystalline, grayish white salt with a little interbedded gray shale - somewhat calcareous	6358	6418
Dark brownish gray, very calcareous shale	6418	6447
Coarse, crystalline, grayish white salt with considerable interbedded dark gray shale - somewhat calcareous	6447	6453
Dark brownish gray, very calcareous shale	6453	6489
Coarse, crystalline, grayish white salt with a little interbedded dark gray shale - somewhat calcareous	6489	6508
Very fine, dense, very dark brownish gray argillaceous limestone	6508	6519
Gray to brownish gray calcareous shale	6519	6530

VERNON SHALE (Bloomsburg)

Light greenish gray shale - somewhat calcareous	6530	6644

Light greenish gray shale - slightly calcareous	6644	6688
Light greenish gray shale	6688	6732
Light greenish gray shale - slightly calcareous.	6732	6775
Dark gray shale - somewhat calcareous - contains a little anhydrite	6775	6805
Light greenish gray shale - slightly calcareous	6805	6881
Interbedded light greenish gray and dark gray shale - somewhat calcareous	6881	7025
Light greenish gray shale - somewhat calcareous with some interbedded brownish red shale - also somewhat calcareous	7025	7034
Purplish red shale - somewhat calcareous (2-inch anhydrite seam or lens at 7060 feet)	7034	7125
Purplish red shale - slightly calcareous	7125	7148

Structure

Two anticlines, the Sabinsville and the Wellsboro, cross the county in a north of east direction. In addition the axis of the Harrison anticline touches the northwest corner of the county, the Marshlands anticline extends for a short distance into Gaines Township, the Slate Run anticline a short distance into Morris Township and the axis of the Towanda anticline crosses the southeast corner of the county. The synclines named from north to south are the Cowanesque, Pine Creek, and Blossburg. All of these are well defined folds which, as shown in Figure 1, possess marked continuity.

The surface expression of the folds is indicated on Figure 3. Evidence of doming is observed on the Sabinsville anticline in Farmington and Lawrence townships and in Clymer Township; on the Wellsboro anticline in Elk, Delmar, Charleston, and Richmond townships; and on the Towanda anticline in Union Township. In all of the domed areas the south limb is appreciably steeper than the north. The regional plunge of the folds is to the southwest.

In general the folds that occur along the edge of the Allegheny Plateau decrease in amplitude with distance from the Allegheny Front. This is best illustrated in Tioga County by the synclines. The Blossburg basin is deep enough to have preserved Allegheny beds; in the Pine Creek basin there are large areas of Oswayo and some Pottsville, while in the Cowanesque basin the youngest rocks are Oswayo. The point is not illustrated by the anticlines in this area due to the exceptional height of the Farmington Township dome.

The amplitude of the folds in the north half of the county has been determined by contours drawn on the base of the Catskill red beds* and for the rest of the county has been calculated from dip data. Maximum values are ap-

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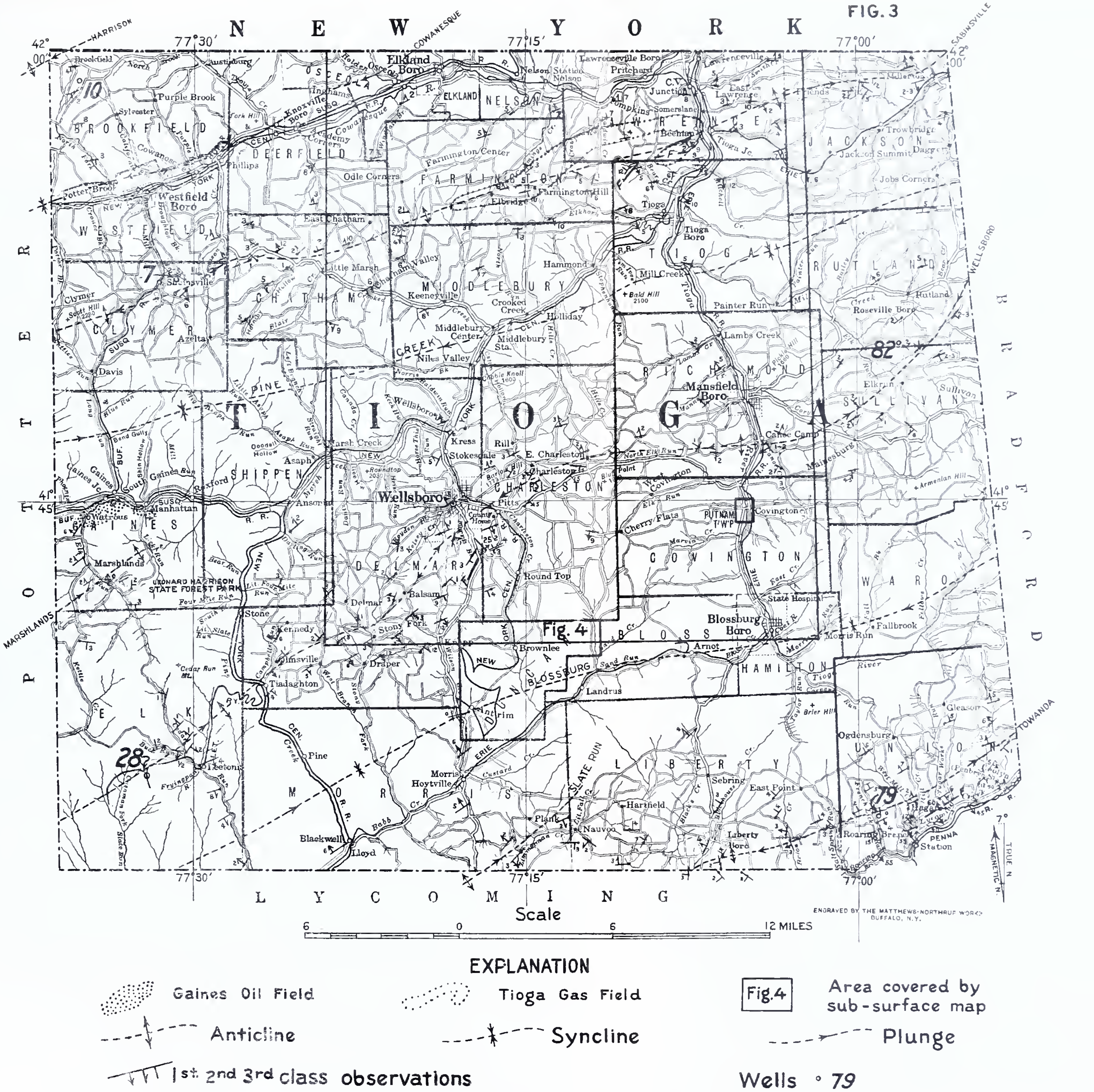
* U. S. Geological Survey folios Nos. 92 and 93.

FIG. 3



STRUCTURAL GEOLOGY INTERPRETED FROM STRIKE AND DIP DATA.

proximately as follows: Harrison anticline - Cowanesque syncline 1,000 feet, Cowanesque syncline - Sabinsville anticline 1,200 feet, Sabinsville anticline - Pine Creek syncline 2,000 feet, Pine Creek syncline - Wellsboro anticline 1,500 feet. Wellsboro anticline - Blossburg syncline 2,500 feet.

Surface evidence of faulting is observed on the south flank of the Sabinsville anticline in Chatham, Tioga, and Lawrence townships, on the Wellsboro anticline southeast of Wellsboro, and on the Towanda anticline in Union Township. The evidence is too indefinite to serve a constructive purpose, amounting to scarcely more than an indication of probable faulting. No evidence of faulting was observed elsewhere in the county. There are, however, other examples of faulted structure in this region. East of this area the south flank of the Towanda anticline shows dips up to 90 degrees and is visibly faulted; likewise, the Wellsboro anticline in Ridgebury Township, Bradford County and the Harrison anticline in Norwich Township, McKean County are visibly faulted, and at Hebron Field in Hebron Township, Potter County there is surface indication of faulting comparable to that observed at Tioga Field.

The map (Fig. 3) should be considered a detailed reconnaissance effort. A strike and dip representation of structure is demanded by the number, distribution, and the quality of surface exposures. The absence of readily recognizable key beds makes structure contouring impracticable in reconnaissance work.

SUMMARY OF ORISKANY DEVELOPMENTS IN TIOGA COUNTY

During the three years since discovery of Tioga Field 101 locations have been active in Tioga County. See Figures 3 and 4. Ninety-two wells have reached the Oriskany, 43 are producers, 49 are dry holes, and 6 have been abandoned above the sand. One well is now drilling and 2 are shut down. The initial volume of the successful wells ranges from 85,000 to 70,000,000 cubic feet in 24 hours with rock pressures of 1460 and 1675 pounds per square inch. The average initial volume of the wells completed is about 15,000,000 cubic feet and the aggregate volume about 628,500,000 cubic feet a day.

All the successful wells are located in Tioga (Farmington) Field. Of the successful holes 21 may be said to be within the limits or on the edge of Tioga Field and the remainder are distributed as follows: flanks of Tioga dome 10, elsewhere on the Sabinsville anticline 3, Harrison anticline 1, Wellsboro anticline 7, Towanda anticline 1, synclines 6.

Over 90 per cent of the probable productive area of Tioga Field is held by five large companies. To these companies are credited 41 of the successful wells drilled and 21 of the dry holes. The total volume of company-owned wells is 627,886,000 cubic feet. Independent operators (many small) have drilled 2 wells that together had an initial volume of 585,000 cubic feet and 28 dry holes. The field probably is less than half drilled up.

TIOGA FIELD

Structure on the Oriskany sand

Development of Tioga Field had not progressed far before it was evident that a subsurface condition existed for which there was no adequate surface expression. Dry holes were drilled in what had been considered favorable structure position. The reflection seismograph was then employed to outline the structure on the Oriskany sand.

Figure 4 is an interpretation of subsurface conditions based upon the well data that is summarized at the end of the paper, supplemented by a considerable number of seismograph readings. The map makes no pretense of finality. Figures 3 and 4 afford a comparison between surface indications and probable structure at the producing horizon. Cross sections of Tioga Field are shown in Figure 5.

The outstanding structural element of the field is a block fault half a mile to 1 mile wide on the south flank of the anticline and just south of the axis. The north fault has been intersected by the Kemp (43), A. C. Smith (48), and the Middaugh (73) wells, the south fault by the Whitney (39) and the Meaker #2 (77) wells. The bounding fault surfaces appear to dip steeply toward the north, in which direction also the block is tilted. As a result, the fault block area is upthrown with respect to the rest of the south limb of the anticline and downthrow with respect to the axial area of the anticline. Also, the surface of the block itself is deformed into an anticline along which occur three domed areas.

The principal axis of the field - the axis of the Sabinsville anticline - is 2,000 to 2,500 feet north of the fault block area. The field occupies a dome on this anticline which here maintains a high rather even crest for more than 12 miles, beyond which the plunge both to the southwest and to the northeast is rapid. Along the crest are two subsidiary domes that show maximum closure of about 300 feet.

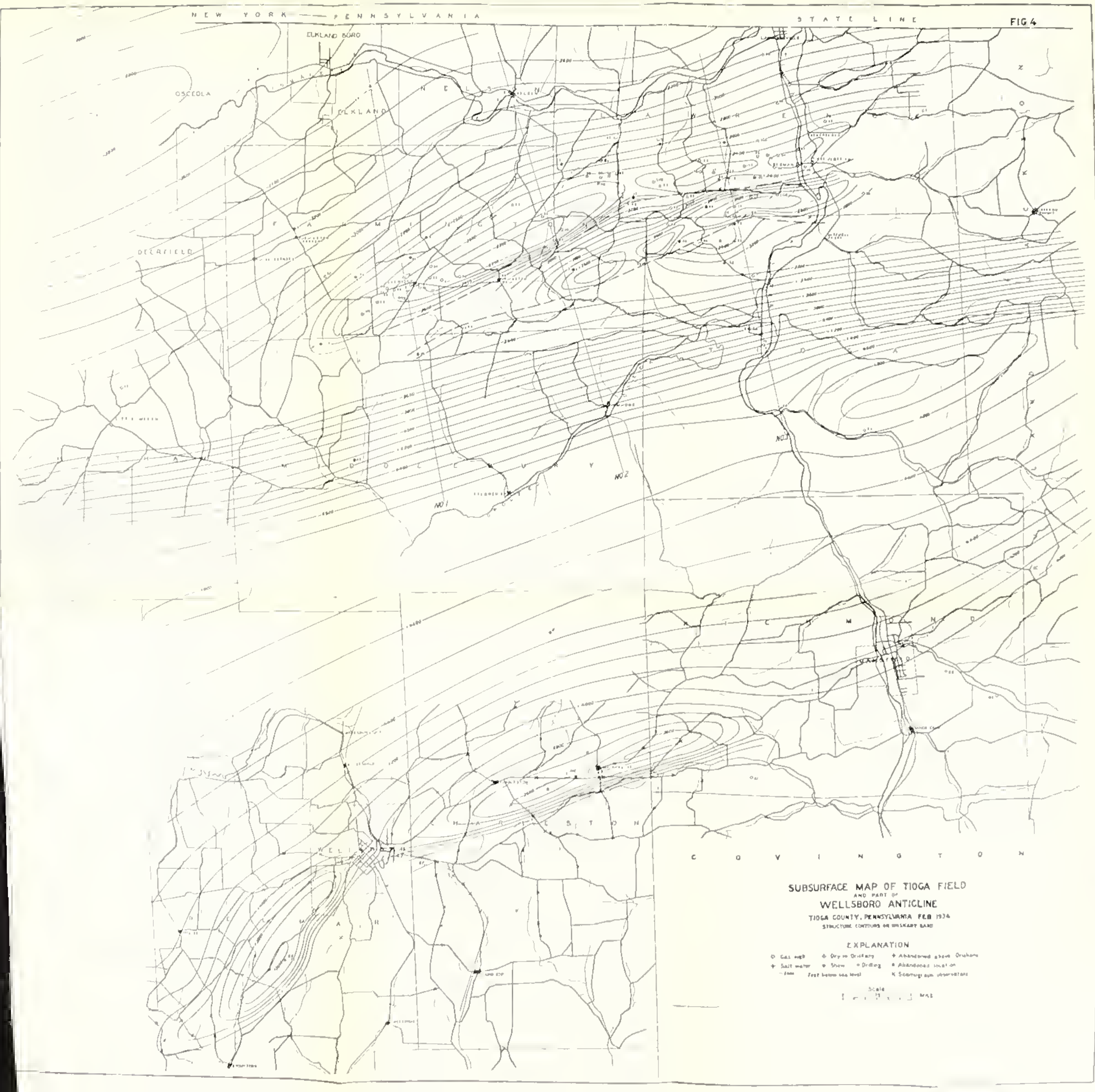
The axial area adjacent to the north fault of the block has been only slightly deformed by the fault movement, deformation taking the form of local steepening. The south limb of the fold adjacent to the south fault of the block has been more noticeably affected. Just west of Tioga River this limb shows a definite reversal of dip.

Subdivisions of the field. Basing subdivision primarily upon response of rock pressure to gas withdrawals it is now recognized that the field consists of three independent pools, the Meaker, the Boom, and the Elbridge.

The Meaker pool is on the east dome of the fault block and includes wells Nos. 3, 17, 18, 25, and 104. Effective closure in this pool is about 100 feet and the average initial rock pressure was about 1,600 pounds. The rock pressure is not affected by gas withdrawals on the main anticline.

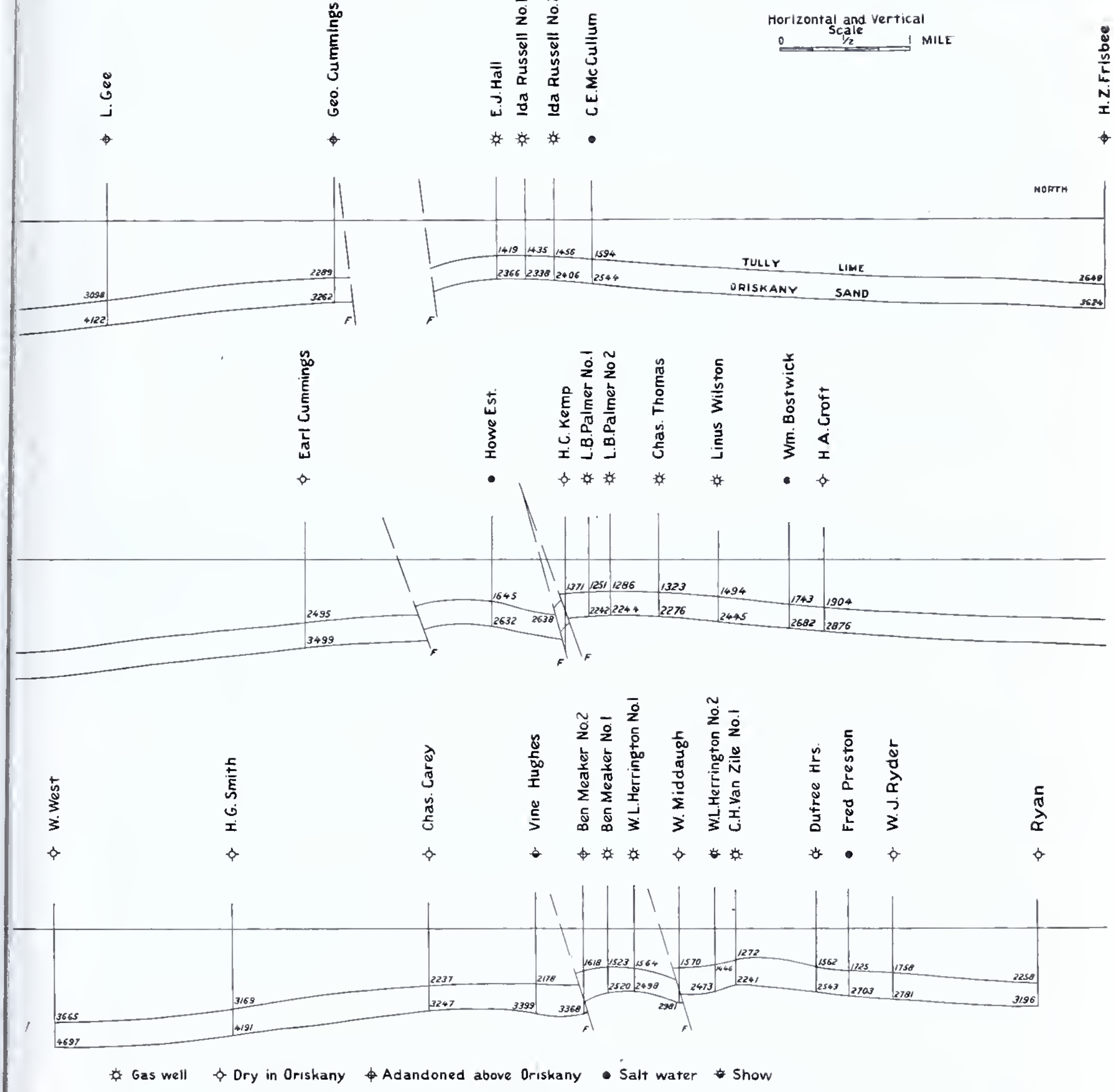
North of the Meaker pool on the main anticline is the Boom pool and

FIG 4



SUBSURFACE MAP OF TIOGA FIELD
AND PART OF
WELLSBORO ANTICLINE
TIOGA COUNTY, PENNSYLVANIA FEB 1934
STRUCTURE CONTOURS ON ORISKANY SAND

FIG. 5



VERTICAL SECTIONS, TIOGA FIELD

at the west end of the field, centering around Elbridge, the Elbridge pool. The Elbridge pool includes all wells as far east as the Leslie (59); the Boom pool all wells from Wilston (84) east to Tioga River except those of the Meaker pool.

Effective closure in the Boom pool is about 320 feet, in the Elbridge pool about 285 feet; both pools had an average initial rock pressure of about 1,600 pounds. While the behavior of pressures under the stress of gas withdrawals indicates the complete independence of these two groups of wells, the line of division has not yet been determined. The presence of a cross-structure fault between the Leslie and Palmer wells is suspected and is partly confirmed by seismograph results, but neither its presence nor position has definitely been determined.

For purposes of discussion the field may be divided into its elements as follows:

The main anticlinal:	Elbridge section, Boom section, section east of Tioga River, Little Marsh section, Sabinsville section.
The fault block:	Meaker section.
The south flank:	Mitchell Creek section.

As noted above, the dividing line between the Elbridge and Boom sections is as yet undetermined but is known to fall between the Leslie (59) and the Wilston (84), Thomas (90), Palmer (42)(44) group of wells. As pictured on Figure 4 this would not be a natural subdivision of the field, but the discrepancy probably is due to incomplete structural data which can be supplied only by further drilling.

All the wells north of the fault block from Wilston (84) east to Tioga River produce as a unit, effective closure extending below the depth of the saddle that falls between Farr #1 (6) and the Farr #4 (100) wells.

The section east of Tioga River has not been adequately explored. Only two wells have been drilled here. Both wells encountered the Oriskany at an elevation that would be within the limits of production west of the river and both found sand conditions favorable but the wells are dry. No explanation based upon adequate data is available. It has been suggested* that where Tioga River crosses the anticline there is physiographic** evidence that the river's course is controlled by a fault. The close proximity of proved faults in Tioga Field and the probability that a cross structure fault occurs between Elbridge and Boom pools supports this assumption. Such a fault might have had an important influence on accumulation.

The structure east of the river may be complicated by the extension of the Meaker fault block into this area. Further exploration is necessary before this section can be condemned.

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*Bulletin 102-A, Pennsylvania Topo. and Geol. Survey, 1931.

**Topographic sheet, Tioga Quadrangle.

Only one well, the Davis (21), has been drilled in the Little Marsh ection. It found the Oriskany about 450 feet below effective closure in ioga Field. Sand conditions were satisfactory but the well is dry. Surface ata are few in this area but west of Little Marsh there is rather definite urface evidence of faulting. In view of the probable variation between surace and subsurface structure in the presence of faulting this section also will equire further investigation before it can be condemned.

West of the faulting observed near Little Marsh the axis rises and a dome s developed in Clymer Township (Fig. 3). The Ackley well (7), located on this ome near Sabinsville, found the Oriskany 125 feet lower than the Davis (21) and lso is dry. It is not improbable that the south limb of this dome is affected y the faulting observed just east of it.

The Meaker anticline, on the fault block on which the Meaker pool is located, shows three domes of about equal structural height. The domes are eparated from each other by saddles that are deeper than effective closure n Meaker pool which is on the east dome. It is not improbable therefore that he other domes on this anticline may prove productive.

In the Mitchell Creek section closure is suggested south of the fault block. Several wells drilled in this area are dry but the information ast of the Carey (41) well is so limited that we do not know whether or not productive closure may exist here.

More than average significance should perhaps be attached to the comparison afforded by Figures 3 and 4 as this field is the only instance available that permits an appraisal of such terms as surface indication, fault indication, structural high, etc., when used by the field geologist in northern Pennsylvania. Moreover, it has been made available early in a development campaign that may eventually be extended throughout some ten or twelve thousand square miles in northern Pennsylvania.

This field, the Hebron Field, and each isolated successful well has shown gas accumulation in the Oriskany sand to be closely related to structural highs. Further, the Oriskany sand by comparison with the "shallow" oil and gas sands of the western Pennsylvania fields is a continuous sand. It is known to cut out or to become an ineffective reservoir locally but it is not lenticular or variable in reservoir capacity to the degree common among the "shallow" sands. The producing characteristics of the Oriskany and of the "shallow" sands will therefore be different. Throughout much of western Pennsylvania accumulation in the shallow sands is not closely related to structural highs; extent of the sand, porosity, and water conditions appear to have had a greater influence on accumulation than had structure. Accumulation in the Oriskany sand can be expected wherever structural highs occur, and preliminary exploration, at least, should be carefully located on structure.

Likewise a value has been put upon any surface indication of faulting. At Tioga Field and at Hebron Field the surface indications of faulting were too meager to permit more than a forecast of its presence, yet the element of faulting has proved a very important consideration in field development. Where faulting is suspected, geophysical investigation should precede extensive drilling.

In general, we have perhaps been too ready to think of Allegheny Plateau folds as being essentially regular and uniformly simple, minor geologic features that are expressive of the dying out of those forces that produced the highly folded and faulted Appalachian Valley Province just east of the Allegheny Front. In a regional way that concept is not incorrect, but Tioga Field experience indicates that the oil and gas geologist in considering Oriskany development must measure his structures differently. In Tioga Field effective closure in the several pools varies between 100 and 320 feet; the apparently simple fold is effectively broken so that dry holes (costing $18,000) and 20 million foot wells have been drilled within a few hundred feet of each other. Viewed from this angle the regional idea of essential simplicity is inadequate.

Analysis of faulting. The effect of part of the fault movement, at least, is definitely known. That it is not an overthrust from the south, as might have been expected, is evident but just what the nature of movement has been is not so clear. One opinion, based upon the observation that displacement at the Meaker well, for instance, is down on the southeast would classify the break as an underthrust. This classification may be objected to on the ground that underthrusting commonly implies intensive deformation in which the tangential component of force is the dominant element. The break might more readily be explained as controlled by the vertical, rather than by the tangential components of the deforming force. This view assumes the most of the thrust to which the Allegheny Plateau region was subjected was transmitted through the deeply buried but highly competent Cambro-Ordovician and older strata; above these rocks there seems to be no thickness of competent beds capable of performing the function. If so, the deformation now observed at the surface might have resulted from forces the major component of which was the vertical one, the tangential force being inferior and in effect complimentary to the deep-seated thrust.

A tangible bit of evidence in support of this idea is the fact that in some wells displacement at the Oriskany horizon is greater than at the Tully horizon 1,000 feet above the Oriskany. This suggests that the faults originated at depth and were partly absorbed by adjustment within the overlying thick shaly part of the section.

The assumption of either overthrusting or underthrusting as the fundamental principle of deformation would permit operators to project determined geology into unexplored parts of the field; a certain regularity could be expected that would justify the use of projected geology in directing exploration. The sort of break postulated above is likely to show very little regularity. It, in effect, might be compared to a collapsed arch. The two faults mapped in the east end of the field enclose a block or wedge, that, at the locality of the Meaker well, is tilted north. Followed west these faults may be expected to merge; followed down, the direction of inclination of the fault surfaces may change; the block itself may be faulted (Fig. 5) and the direction of tilt reversed. In addition we may expect complimentary faults. A cross fault separating the Elbridge and Boom pools would be permissible in this system as also would a fault or faults that branched off from the known faults below the present surface.

As seismograph data are not always dependable in the immediate vicinity of faults, considerable still remains to be determined by drilling to complete our information on faulting in this field.

Critical horizons

Two satisfactory horizon markers occur above the Oriskany sand and are recorded in all wells, (1) the Tully limestone which, because of the interval separating it from the Oriskany, is locally called the "1,000-foot lime" and (2) the Onondaga limestone which immediately overlies the producing sand.

The Tully limestone commonly is a very fine-grained, dense, dark brownish-gray limestone that may include dark gray calcareous shale. Cuttings from this lime are distinguished by their tendency to have a decidedly cubic form which is in contrast to a flaky form observed in cuttings from other limestones. The coloring, also, is characteristically mottled light and dark.

Identification of the horizon is essential. Most wells start in the Chemung and the rocks above the Tully present such a monotonous sameness that, in view of the structural hazards of the district, it is seldom possible to predict the depth to the Oriskany until the Tully is reached.

The thickness of the Tully as known ranges between 47 and 105 feet and averages about 75 feet. It appears to be greatest in the central part of the county and to thin toward the north and west. The interval between the top of the Tully and the top of the Oriskany as known varies between 737 and 1370 feet but averages about 1,060 feet. Below are tabulated measurements of thickness and interval by townships.

Distance from Tully limestone to Oriskany sand and thickness of Tully

	Tully - Oriskany			Tully		
Township	Wells		Interval	Wells		Average thickness
Elk	1		941	1		77
Clymer	1		1,327			
Chatham	1		855	1		61
Brookfield	1		737	1		63
Rutland	1		1,211			
Union	1		1,370			
Delmar	1		1,012	1		84
Charleston	2		1,193	1		90
Richmond	1		1,210	1		105
Middlebury	2		925	1		79
Tioga	7	wells range 1,010 - 1,221	1,083	6	wells 60 - 84	71
Farmington	21	" " 868 - 1,352	970	14	" 59 - 85	70
Lawrence	38	" " 950 - 1,411	1,023	26	" 47 - 86	68

Lithologically the Onondaga is a dense, dark gray limestone. As both the Onondaga and the Tully are overlain by black shale, in exploratory wells the two limes have sometimes been confused. Further, stray limes that appear above the Onondaga may be confused with the Onondaga.

As the horizon at which the production string of casing must be set to insure security in handling the high rock pressures encountered in the Oriskany is near the base of the Onondaga it is very important that the Onondaga be accurately identified. Fettke* offers the following criteria: - - - "after the first or second screw has been drilled in the Onondaga the cuttings almost invariably contain particles of a brown shale which is present in the basal portion. These brown particles are easily recognized if the cuttings are examined under water on a watch glass." This means of identification is in general use by operators.

The thickness of the Onondaga varies between 10 and 89 and averages about 30 feet. The range and average thickness, as known in the several townships, is as follows:

Thickness of Onondaga limestone, in feet

Township	Wells	Range	Average	Township	Wells	Range	Average
Elk	1	-	22	Charleston	1	-	21
Clymer	1	-	33	Richmond	2	45 - 40	42
Chatham	1	-	25	Middlebury	2	79 - 10	44
Brookfield	1	-	24	Tioga	7	20 - 26	22
Rutland	1	-	69	Farmington	27	11 - 60	26
Union	1	-	89	Lawrence	44	11 - 48	24
Delmar	1	-	29				

In general** the Oriskany formation where it outcrops in Pennsylvania is a fine-to coarse-grained, friable, light-colored sandstone but in detail its lithology varies considerably from place to place. Locally it may be conglomeratic in part and may include shaly, cherty, ferruginous or calcareous phases. In eastern Pennsylvania outcrops of Oriskany are dominantly sandy to conglomeratic; in central and south central Pennsylvania chert becomes prominent to dominant; in northern Pennsylvania the basal Oriskany tends to be a decidedly calcareous sandstone and the upper part slightly calcareous. In some areas the sandstone member is absent and locally the entire formation is missing, due apparently in some instances to erosion and in other instances to hiatus in deposition.

The lithology of the sand in Tioga field as indicated by drill cuttings and fragments blown from wells is reported by Fettke*** as follows:

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*Fettke, C. R., Pennsylvania Geol. Survey, Mim. Bull. 102-B, p. 8, 1931.

**Personal communication, B. Willard, Pennsylbania Geol. Survey.

***Pennsylvania Geol. Survey, Mim. Bull. 102-B, p. 1, 1931.

"This (the sand) consists of a rather tightly cemented, comparatively pure, medium-grained quartz sandstone ranging in color from light gray to light brownish gray. In thin section, under the microscope, fragments blown from the productive portions are made up almost entirely of an interlocking mosaic of quartz grains possessing average diameters in the coarser portions between 0.5 and 1.5 millimeters and in the finer portions between 0.3 and 0.4 millimeters. In thin section the majority of the grains appear to be angular or subangular, but careful examination in many instances reveals this angularity in part at least is due to the secondary crystalline outgrowth of silica from grains that originally were round. Such secondary silica is the chief cementing material. Thin sections of fragments from the upper portion of the sandstone blown from productive wells, as a rule, contain only a very small amount of calcite irregularly distributed among the quartz grains. This is in marked contrast to the lower portion of the sandstone which, in places where it has been penetrated by nonproductive wells, is almost invariably markedly calcareous. The upper portion of the sandstone in nonproductive wells, though not as calcareous as the lower, is usually at least slightly calcareous. Inasmuch as all the productive wells stop in the upper portion, where the gas is encountered, it is not known whether the lower portion in these wells also is calcareous."

In this county the Oriskany sand has been encountered in every well completed to the Oriskany horizon. In adjacent counties it is absent locally. Only wells that failed to find gas have penetrated the sand and given a measure of its thickness. In Tioga Field the thickness is about 45 feet. The measurements available in the several townships are as follows: Elk 26, Clymer 36, Chatham 28, Brookfield 23, Rutland 55, Delmar 61, Charleston 2 wells, range 25-44, average 35, Tioga 17, Farmington 3 wells, range 21-60, average 43, Lawrence 6 wells, range 37-69, average 51.

Porosity. No cores of the Oriskany have been taken in this region. Porosities are determined upon pieces of sandstone blown from wells when they are drilled in. The following are examples of results obtained:

Porosity of Oriskany sand

Well	Porosity	Initial volume
Wilston & Kuhl	10.6[1], 10.0, 10.4	13,500,000
Leslie, J. A.	9.2[1], 8.7, 9.1, 9.8, 10.1, 10.1, 10.7, 11.1, 11.8	40,000,000
Palmer #1	7.4, 7.4, 7.7, 8.5	22,000,000
Farr #1	4.0, 4.1, 4.9, 5.0	10,000,000
Close,E.W., #1	10.1	25,000,000
Ashton #1	7.9, 8.5, 8.6, 8.7, 9.5, 10.0	10,100,000
Close, E.W.,#2	10.2, 11.2	13,000,000
Herrington #1	10.2, 10.2, 10.6	25,000,000
Boom #1	11.1	20,000,000
Russell,Ida #2 ((4,106')	8.2, 8.3, 8.3, 9.6	12,000,000
((4,110-4,119½')	10.0,10.3	
Fletcher #1	8.7, 9.4, 9.5, 9.8	3,000,000
Smith, Jesse #1	2.9, 3.0, 3.4, 3.6	6,000,000
Barcroft #1	9.8, 10.6	6,000,000
Colegrove #1	8.0, 8.5	2,500,000
Hoyt #2	8.2, 9.7, 9.8	7,250,000
Learn #1	10.0	22,000,000
Russell,Ida #1	8.4, 9.5, 10.3, 10.7	10,000,000
Van Zile #1	8.9, 10.6	33,000,000

[1] Point Breeze Laboratory of Atlantic Refining Co., Philadelphia. Others by C. R. Fettke, Carnegie Institute of Technology, Pittsburgh.

The average porosity of the 61 samples from 18 wells cited above is 8.8 per cent.

A suite of samples from 19 wells in the Wayne-Dundee, Tioga, and Hebron fields is reported* to show an average porosity of 8.97 per cent, a maximum of 10.62 per cent and minimum of 5.97 per cent. Two specimens** from Nugent #1 well, Hebron Field, Potter County show 9.1 and 9.6 per cent porosity.

No close relation between porosity and volume is apparent. Neither perhaps is the maximum volume of wells in the field (70,000,000) entirely consistent with the porosities observed. These possible discrepancies may perhaps be explained by the fact that only the tightest part of the sand may be ejected from the wells as fragments and the test therefore may not be representative of the sand as a whole. Further irregularity in the sand that may explain its unexpected capacity is the presence of minute fissures, many of which are partly sealed by terminated quartz crystals that project from the walls. It would seem that the capacity of the reservoir has been augmented by fracturing incident perhaps, to faulting of the structure.

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*Torry, Fralich, and Simmons, Bradford, Pa.

**Fettke, C. R.

Locally, but more especially high on the south flank of the structure, wells find the Oriskany to be very hard and dry - showing neither gas nor water. The sand apparently is incompetent. Absence of pore space here may be due to complete recementation of the sand by silica. Presumably, the sand shattered most near the fault surface and along this shattered zone siliceous solutions found an easy avenue of circulation. Here deposition from solution resulted in complete closing of both fractures and pores. At a distance from this main channel of circulation fractures and pores commonly are but partly closed, and it is here that we note their presence and the presence of secondary quartz.

Occurrence of gas. The gas commonly occurs within 18 inches of the top of the sand. Not infrequently volumes of several million cubic feet under 1600 pounds rock pressure develop when the sand has been penetrated but a few inches. The tools are withdrawn and the well left to drill itself in. The best pay occurs within 6 feet of the top of the sand, although in a few instances additional gas has been obtained up to 15 feet in the sand.

The top of the sand usually is very hard, a bit being in bad condition after drilling but a few inches.

Analysis of the gas from Palmer #1 well.*

Carbon dioxide	0.0	Methane	99.5
Illuminates	0.0	Ethane	0.0
Oxygen	0.1	Nitrogen	0.4
Carbon monoxide . . .	0.0	Specific gravity	0.58
Hydrogen	0.0	B.t.u.	1030

Samples from Burdett #1 and Meaker #1 wells also show a B.t.u. value of 1030

*Courtesy of Allegheny Gas Company

Occurrence of salt water is indicated by convention on Figure 3. Along the anticlinal axis on which the Elbridge and Boom pools are located salt water occurs principally on the north flank; on the south flank the sand drills very hard, as though too tightly cemented to serve as a reservoir for either gas or water. Only one well on the south flank, Farr #2, has shown salt water in great amount and this well is located in saddle position, a possible influencing factor. On the Meaker anticline salt water occurs on both the north and the south flanks. No well has found salt water far down the flanks of the Sabinsville anticline or in the synclines.

On the main anticline gas occurs throughout an area about 1 mile wide that shows between 285 and 320 feet of closure; salt water is encountered in a belt about 1,800 feet wide that shows a difference of elevation of about 200 feet. On the Meaker dome the water belt is about 700 feet wide and occupies about 100 feet of closure. It does not seem likely that the salt water present is sufficient to flood all of the proven gas area.

The absence of water on the south flank of the main anticline is probably due to tightness of the sand that has resulted from recementation by silica of shattered sand in proximity to the fault. This presumably incapable sand is drilled only with great difficulty. In the synclines and on the flanks of the anticline below the water zone the sand drills easily. No cores have been taken but if incapable the rock here probably is completely cemented by lime or iron oxide rather than by silica; if not incapable the sand presents an unorthodox water situation. Not only is the water zone suspended on the flanks of the fold, but locally on the north flank of the main anticline it does not appear to be in contact with the gas, as tests drilled near the gas-water line have found neither present.

It is improbable that the localization of water within the sand has confused field observations for in almost every instance water when present is found within 6 feet of the top of the sand and in most dry holes the sand has been drilled through. It would seem that an explanation is unwarranted until a core has been taken of the dry sand from the flank of the fold. Until then, we should perhaps assume that the sand below the water and between the water and the gas is incapable of serving as a reservoir.

Since the field has been on production two gas wells (6 and 32) have begun to show salt water and one (97) is reported to be drowned out.

The following analysis of salt water is from the Oriskany sand in the Frank Wheeler well (29).

Analysis of salt water from Oriskany sand*

	Parts per Mil. (Mgms. per Kgms.)		Parts per (Mgms.per K
Silica (SiO_2)	(a)	Carbonate (CO_3)	0
Aluminum (Al)	(a)	Bicarbonate (HCO_3) . . .	0
Iron (Fe)	d/ 71.2	Sulphate (SO_4)	2
Calcium (ca)	47,200	Chloride (Cl)	172,300
Magnesium (Mg)	5,790	Bromide (Br)	570
Sodium (Na)	47,400	Iodide (I)	(f)
Potassium (K)	1,276	Total dissolved solids	280,000

(a) Not determined
d/ Includes 6.2 p.p.m. precipitated at time of analysis
(f) Less than 1 p.p.m.
S. K. Love, analyst.
*Collected by C. R. Fettke for the Pennsylvania Geol. Survey

Capacity of the field

It has been estimated that the approximate content of the sand per acre was originally 10,000,000 cubic feet. As the proven area of the field as now outlined is about 7,100 acres, this estimate would give a total original reservoir content of 71,000,000,000 cubic feet.

Any estimate based upon sand thickness, porosity, and area can only be approximate. In another paragraph it is shown that there is little apparent relation between observed porosity and well volume and it is suggested that fractures play an important part in determining the reservoir capacity. Also as the field is only about half drilled up, and the effect of faulting not entirely known, the productive area figure may be in error.

A closer approximation may be made by calculating from the withdrawal per pound drop in pressure in each of the three pools. In the Elbridge pool the average initial rock pressure was about 1600 pounds and September 1, 1933 was about 1050 pounds. About 3,774,000,000 cubic feet of gas had been taken from the pool, which indicates a drop of one pound for each 6,862,000 cubic feet withdrawn and an original reservoir content of something like 10,979,000,000 cubic feet.

The average initial pressure in the Boom pool was about 1600 pounds and September 1st it was about 1300 pounds. Withdrawals totaled about 5,944,200,000 cubic feet, which indicates a drop of one pound for each 19,814,000 cubic feet and an initial reservoir content of 31,702,400,000 cubic feet.

Similarly the pressure drop in Meaker pool is from 1600 to 1510 pounds, the withdrawal 1,070,000,000 cubic feet, the pressure drop one pound per 11,889,000 cubic feet, and the original reservoir content 19,022,400,000 cubic feet. It should be noted that a large part of the gas withdrawn from the Meaker pool was lost while Meaker #1 well, which came in wild, blew perhaps 70,000,000 cubic feet a day into the air for a period of 14 days. It was uncontrolled production not accurately measured, while production from the other pools was measured.

The total original content for the field would by this method appear to have been about 61,703,800,000 cubic feet.

The current value of gas at the well is about 12 cents per thousand cubic feet; the value of the gas originally contained in the reservoir about 7 million dollars.

Notes on field development

Acreage within the proven area of the field is held as follows:

	Acres
East Penn Development Company . . .	3,724
Lycoming Producing Corporation . . .	1,835
The Penn-United Gas Company	902
Mellon-Pollock	260
North Branch Development Company . .	385
Total	7,106

The usual lease term is 5 to 10 years. Rentals commonly vary between 25 cents and $1.00 per acre annually. Soon after discovery rentals ranged up to $10.00 an acre and in many instances substantial cash bonuses were paid for the first year. Previous to discovery of Tioga Field the usual royalty paid in this region was $200 to $300 annually per well. More recent practice calls for 1/8 of the net proceeds from the sale of all gas produced and sold off the premises. In lieu of 1/8, 1½ cents per 1,000 cubic feet may be specified.

Estimates on economic spacing in this field vary between 2,200 feet or one well for 400 acres and 2,640 feet or one well for 640 acres. In the Boom, Meaker, and the west end of the Elbridge pools the acreage set up will in many instances require a spacing of less than 1,000 feet, allowing as little as 40 acres to the well. From about 2 miles east of Elbridge, to the east line of Lawrence Township, all the acreage is held by one company and here a more economic development is possible.

Standard rigs have been used exclusively in drilling. Common practice is: to start with a 12-inch hole, run 50 to 150 feet of 10-inch drive pipe, set 600 to 800 feet of 8-inch water string and cement about 4,000 feet of 7-inch in the Onondaga lime just above the Oriskany sand.

The 7-inch is set in from 200 to 300 feet of cement. During early developments the Halliburton method was used, but as that company found it unprofitable to maintain an organization in this section, other methods had to be adopted. A common practice is as follows: the 7-inch casing is raised from 3 to 5 feet off bottom. A plug is placed in top of the casing and 30 to 35 sacks of Incor cement are poured on top of plug forcing it to the bottom of the hole. A second plug is then forced to the top of the cement with the bailer, and the bailer is left in this position in order that the position of the cement may be known at all times. Water is then run into the hole until sufficient weight has been placed on the plug to force the cement to the outside of the 7-inch casing. One thousand feet of water usually accomplishes this purpose. The casing is then lowered to the bottom of the hole.

The presence of shale gas in most wells makes the use of an 8-inch casing head a necessary part of the well head equipment. In the larger wells it is customary to reduce from 7 inches down to 4 inches for the "christmas tree". The "christmas tree" is composed of a cross of four 4-inch openings with two 4-inch valves on the horizontal limbs for shipping gas and one 4-inch valve on the vertical limb for blowing off the well and to regulate the taking of pressures.

Two of the major companies in the field originally adopted the system of regulators and heaters to reduce pressure for shipping gas. Other companies finally adopted a plan whereby no regulators or heaters are necessary. A restriction plate somewhat similar to an orifice plate is used. The upstream side of this plate is beveled and two cross wires are welded over this beveled opening. The plate with opening sufficiently small to hold the desired back pressure is placed in a flange in the 4-inch lead line between well and drip. Very little trouble with freezing is experienced and excellent charts commonly are obtained. When, however, the plate alone does not give satisfactory results, an alcohol bottle is installed on the line on the upstream side of the plate and so adjusted that alcohol at the rate of about 60 drops per minute is forced inside the line at the face of the plate and freezing is eliminated.

The cost of a well is about $18,000 distributed as follows:

Cost of a well in Tioga Field

Building road and clearing location	$ 100.00
Digging and cementing cellar	85.00
4100' of drilling, contract price $2.50 per foot	10,250.00
100' of 41.85# - 10" drive pipe	214.00
10" drive shoe	27.00
700' - 24# - 8¼" casing	840.00
4002' - 24# - 7" O.D. standard seamless casing	4,380.00
Hauling casing to location	150.00
Cementing 7" casing, 33 bags of cement	26.40
Halliburton cementing cost	225.00
Well head fittings (3-4" - 1500# W.P. plug valves (1-6-5/8" x 10" - 1500# W.P. plug (valve and other connections	925.00
Derrick, water and fuel furnished by contractor	
Total cost of well	$ 17,222.40

At the time Tioga Field was discovered the only pipe line outlet available was a 6-inch line that traverses Cowanesque valley and is owned by the Allegheny Gas Company (East Penn Development Co.), drillers of the discovery well. Gas from the field was immediately turned into this line and distributed locally and in adjacent New York State.

In 1931 Susquehanna Gas Company (North Branch Development Co.) (P.P.&L.) built a 14-inch line from Tioga Field to Williamsport, Penna., connecting with preexisting lines, to serve that region as far south as Selinsgrove.

In 1932 the New York State Natural Gas Corporation, affiliate of the Lycoming Natural Gas Corporation (S. O. N. J.), completed a 20-inch line to Syracuse, New York. In 1933 this line was extended (10") from Tioga Field to Hebron Field, Potter County.

Gas is shipped from the field by Lycoming Producing Corporation, North Branch Development Co., and East Penn Development Company. September 1, 1933 about 10 billion cubic feet had been withdrawn by these companies in approximately the proportion 2, 1 and 7 per cent respectively. Both Lycoming and North Branch Development Co. are purchasers in the field, the Lycoming holding the major purchasing contracts. An average price at the well is about 12 cents a thousand. Some contracts provide for an increased rate after a specified period and also for a bonus when the sales price exceeds a specified minimum.

Examples of rates at which Tioga gas is marketed in Tioga and Bradford counties are as follows:

Rates for gas delivered

Domestic	-	First	300	cu. ft.	21	cents a hundred
		Next	2,700	" "	10	" " "
		"	4,000	" "	60	" " thousand
		"	43,000	" "	65	" " "
		All over	50,000	" "	50	" " "
Commercial	-	Same except all over 100,000 cu.ft. at 35 cents per thousand.				
Industrial (Glass plants)	-	First	50,000	cu.ft.	60	cents a thousand
		Next	50,000	" "	52	" " "
		"	100,000	" "	45	" " "
		"	800,000	" "	41	" " "
		"	5,000,000	" "	37	" " "
		"	2,000,000	" "	27	" " "
		"	8,000,000	" "	25	" " "
		Over	16,000,000	" "	23½	" " "

Discounts are given and minimum charges specified

In the Williamsport district the charge is by the therm, 1,000 cubic feet of Tioga gas being roughly equivalent to 10 therms. General rate - $1.00 minimum monthly charge for 2 therms, next 13 therms at 20 cents, above 15 therms per month 16 cents per therm. Industrial commercial rate - ranges from $60.00 per month for first 10 therms to 5 cents a therm for all above 20,000. A rural district schedule calls for $1.00 minimum per month for 1 therm, 22 cents for next 14 therms and above 15 therms 17 cents per therm.

In general the prospective industrial markets have not responded to the offer of natural gas so favorably as may have been anticipated. This is evinced by the unfavorable ratio between withdrawals and field potential. As a result both field development and regional exploration were very much restricted in 1933.

OTHER ANTICLINES

Wellsboro anticline. Seven dry holes have been drilled on this anticline, all of which found the Oriskany present and capable of serving as a reservoir. At least three of these wells were located on what, according to surface indications, appeared to be good structural position. Their failure led to a geophysical survey that indicated a marked difference between structure at the surface and structure at the Oriskany horizon. The Lacey (108) well was located on geophysical findings and checked that data rather closely but is dry.

Figure 4 includes only part of the geophysical map of this anticline.

n brief, it was found that the structure between Stony Ford and Canoe Camp is a double-crested affair with a low area that includes the County Home well (37) ocation. Geophysical data further suggests that the steep south flank dips at Stony Fork, and the sharp north swing of the axis is indicative of faulting. urface indication of faulting was observed on a small tributary of Morris ranch just north of where the creek crosses the east line of Delmar Township. he Chemung strata which here have a normal dip of 1 to 3 degrees to the southwest show dips of 4°NW and of 12 to 25°NE. The possibilities of this area have not been fully tested.

Towanda anticline. There is a well defined dome on this anticline in Union Township, the south limb of which shows dips up to 55 degrees. Closure of several hundred feet is assured, but the total drillable area of the dome could not be great.

One well, the Butters (79), was drilled on this dome and is dry. The Oriskany sand was found at -3805 feet but it was extremely hard and probably is too tightly cemented to serve as a reservoir.

The steep south flank dips probably are indicative of faulting as in adjacent Bradford County, where dips of 70 degrees are observed, this limb is visibly faulted. Here, as in Tioga Field, the tight sand probably is the result of recementation of shattered Oriskany near a fault. Additional testing, farther north of the axis, will be necessary to condemn this structure.

Slate Run and Marshlands anticlines. Neither of these anticlines shows any indication of doming in Tioga County.

Gaines oil field is located on the north flank of the Marshlands anticline and at its northern end (See Appendix No. 1).

TIOGA AS A GAS-PRODUCING COUNTY

A map of the oil and gas fields of Pennsylvania* on which the fields are classified according to the dominant product shows an oil-producing belt in the western part of the State extending through McKean, Clarion, Butler, Allegheny and Washington counties, and east of this belt of oil fields a corresponding but wider belt of gas fields. This principal oil and gas fields region of the State is rather remarkable for the high percentage of proven area within its limits, but on its eastern edge the gas belt is characterized by outlying detached pools.

An Isovol map of the region shows that in the northern part of the State the eastern limit of the oil belt is defined, approximately, by the 42.5 isovol and the eastern limit of the gas belt by about the 40.0 isovol. As indicated on Figure 1, Tioga County lies well east of the principal gas-producing belt. The isovols here trend about N.45°E and range from 37.5 at the northwest corner of the county to 20 at the southeast corner. Previous to 1930 a small oil field had been discovered at Gaines (distinctly anomolous) and numerou wells had found small amounts of gas at scattered localities but none had found gas in commercial amounts. The county had long been classed as possible gas territory with the expectation that in it small scattered pools would some day be developed. Exploration previous to 1930 had been confined to sands above the Oriskany, commonly to sands in the Catskill and Chemung formations reached by wells that seldom exceeded 3,000 feet in depth.

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*Oil and Gas Fields Map of Western Pennsylvania, Pennsylvania Geol. Survey, 1932.

The future of Tioga as a gas-producing county would seem to be dependent largely upon further discoveries in the Oriskany sand. Small pools may be encountered in the shallow sands but the lenticular character of these sands in a region that is only "possible" gas territory does not make them attractive subjects for exploration.

PROSPECTS OF DEVELOPING OTHER ORISKANY FIELDS IN NORTHERN PENNSYLVANIA

Since 1931 the Pennsylvania Geological Survey has mapped the structure throughout about 12,000 square miles of the Allegheny Plateau region, from Delaware River on the east to and including McKean, Elk, and northern Clearfield counties on the west. This mapping, done in a reconnaissance way, identifies about 35 domes that may be considered as suitable sites for test wells to the Oriskany sand. Eight of these domes have been tested by 11 wells without succes and on one other dome 2 wells are now being drilled. Four domes have proved productive.

None of the structures tested have been definitely condemned by the few dry holes that have been drilled on them. Success thus far has fallen to wells drilled in areas where the carbon ratio as indicated by isovol lines is higher than in Tioga Field. Tioga Field falls on about the 27.50 isovol. Ten wells have been completed to the Oriskany in areas that lie between the 27.5 and the 20.0 isovols, and all have failed. However, we have reasonable assurance that only one of these wells was favorably located; of the remainder some are known to have been off structure, and others that found the sand tight appea to have been drilled so near to a fault that the sand was completely recemented. In the area where the isovols exceed 27.5, three domes have proven productive and three additional domes have been tested by single wells without obtaining ga (This analysis applies only to Pennsylvania.); on two of these domes the Oriskany sand was found to be absent.

Viewed from the angle of decreasing isovol values it has long been considered probable that in northern Pennsylvania favorability decreases toward the east or southeast; that is, that anticlines lying south and southeast of the Sabinsville, for example, offer poorer chance for the presence of gas, structural conditions of course being equal, than does the Sabinsville or anticlines northwest of the Sabinsville. Results up to now would tend to confirm this hypothesis but, as we have tried to show, the wells have by no means proven that point.

A large investment in leases and pipe lines has been made in this region by several large companies. The return of that investment demands the discovery of new fields, and it is probable that when conditions are opportune further exploratory work will be done.

Map No.	Operator	Well No.	Lessor	Elev.	ully	Elev.	daga	Elev.	any	Elev.	depth	pres.	volume
*1	Lycoming	1	Howe Est.	1743	3388	-1645	4350	-2607	4375	-2632	4391		
2	J. E. Trainer	1	Wm. Bostwick	1509	3252-3315	-1743	4180	-2671	4191	-2682	4197		
3	Penn-United	1	Ben Meaker	1677	3200-3265	-1523	4175	-2498	4197	-2520	4203	1530	73,000,000
4	Lycoming	1	E. W. Close	1755			3993	-2238	4018	-2263	4022	1625	25,000,000
5	"	1	Lyle Shoemaker	1474	2910-2965	-1436	3910	-2436	3932	-2458	7148		
6	"	1	Farr-Colegrove	1367	2690-2760	-1323	3740	-2373	3773	-2406	3782	1675	10,000,000
7	"	1	F. A. Ackley	1934	3723-3783	-1789	4987	-3053	5020	-3086	5083		
8	"	1	Edith Price	1676			4252	-2576	4276	-2600	4285		
9	Adams	1	Adams	1317	4592	-3275					4950		
10	Hope Eng. Co.	1	Jas. Bertch	1840			4840	-3000	4864	-3024	4921		
13	Leonard	1	Cath. Harrison	1049	2470-2550	-1421	3459	-2410	3481	-2432	3750		
14	Lycoming	1	Geo. Boom	1563	2835-2913	-1272	3784	-2221	3807	-2244	3811	1650	20,000,000
15	"	2	Farr-Colegrove	1687	3070-3125	-1383	4171	-2484	4198	-2511	4203		
16	"	1	Chas. Hoyt	1680	3100-3176	-1420	4011	-2331	4030	-2350	4037	1650	13,131,000
17	"	1	W. L. Herrington	1720	3284-3350	-1564	4188	-2468	4218	-2498	4220	1500	25,000,000
18	"	1	M. P. Close	1634	3130-3225	-1496	4104	-2470	4134	-2500	4135½	1500	60,000,000
19	Penn-United	1	G. Burdette	1572	3080-3160	-1508	4112	-2540	4139	-2567	4145	1525	7,000,000
20	Sylvania	1	Elliott Heirs	1506	3150-3227	-1644	4107	-2601	4129	-2623	4134		
21	Penn-United	1	C. A. Davis	1707	3812	-2105	4647	-2940	4672	-2965	4723		
22	Lycoming	1	J. H. Decker	1501			4671	-3170	4695	-3194	4781		
23	"	1	Dollie Place	1849	3310-3380	-1461	4245	-2396	4272	-2423	4280	1625	4,800,000

*For remarks see end of table.

24	Lycoming	2	E. W. Close	1747	3100- 3175	-1353	4005	-2258	4030	-2283	4036	1621	13,000,000
25	"	1	Chet. Ashton	1625	3045- 3117	-1420	3949	-2324	3970	-2345	3977	1675	10.100,000
26	"	2	Chas. Hoyt	1730	3190- 3267	-1460	4099	-2369	4121	-2391	4132	1625	7,250,000
27	Williamsport O.&G.	1	Wm. Bache	1645	3945- 4011	-2300	4865	-3220	4887	-3242	4956		
28	Cayuga Gas	1	Weiboldt	1870	5048- 5125	-3178	5970- 5992	-4100	5992- 6017	-4122	6045		
29	Penn-United	1	Frank Wheeler	1580	3090- 3150	-1510	4295	-2715	4315	-2735	4322		
30	Manufacturing Gas Co.	1	B. Buckbee	1542	3128- 3206	-1586	4230	-2688	4254	-2712	4254½		
31	Lycoming	1	Adrain West	1564	3620- 3690	-2056	4690	-3126	4712	-3148	4760		
32	North Branch	1	M. Burdette	1273	2600- 2655	-1327	3568	-2295	3590	-2317	3647½	1600	2,000,000
33	Penn-United	1	J. E. Tremaine	1005	2310- 2374	-1305	3333	-2328	3355	-2350	3980	1460	150,000
35	Lycoming	1	Chas. Tremaine	1531	3015- 3065	-1484	3979	-2448	3999	-2468	4130		
36	Penn-United	1	S. A. Smith	1558	3295- 3363	-1737	4286	-2728	4308	-2750	4416		
37	Wells Corp.	1	County Farm	1378	4143	-2785	5495	-4117	5516	-4138	5581		
38	Weir-Thorn	1	Cath. Roe	1406	3190	-1784	4162	-2756	4184	-2778	4249		
39	Morgan-Hague	1	M. V. Whitney	1561	3412- 3482	-1851	4741	-3180	4766	-3205	4780		
40	"	1	Ryan	1056	3314- 3364	-2258	4230	-3174	4252	-3196	4298		
41	Wade & Moore	1	Chas. Carey	1038	3275- 3350	-2237	4263	-3225	4285	-3247	4317		
42	East Penn	1	L. B. Palmer	1764	3015- 3100	-1251	3980	-2216	4006	-2242	4012	1665	22,000,000
43	"	1	H. C. Kemp	1712	3083	-1371	4290	-2578	4350	-2638	5375		
44	"	2	L. B. Palmer	1849	3135- 3210	-1286	4061	-2212	4093	-2244	4095	1655	22,500,000
45	"	1	L. R. Manning	1785	3195- 3270	-1410	4075	-2290	4098	-2313	4103	1650	15,000,000
46	"	1	W. A. Davey	1335	4075-								

43	"	1	A. C. Smith	1487	3460-3535	-1973	4558	-3071	4580	-3093	4692		
49	Lycoming	1	Ida Wheeler	1836	4526-4604	-2690	5501	-3665	5522	-3686	5663		
50	Taylor-Lynch	1	M. L. Loveless	1187	4920-5005	-3733	5987	-4800	6010	-4823	6028		
51	Elkland Oil and Gas	1	Burr Van Duzen	1814	4041-4112	-2227			(Estimated) 5016	-3202	4585		
52	"	1	H. Z. Frisbie	1436	4085	-2649			(Estimated) 5060	-3624			
53	Lyons et al	1	Chas. Geralds	1349									
54	Brad-Lawrence	1	W. J. Ryder	1224	2982	-1758			4005	-2781	4068		
55	Vaughn-Rose	1	Geo. Cummings	1756	4045	-2289			(estimated) 5018	-3262	4337		
56	Mellon-Pollock	1	C. H. Van Zile	1523	2795-2855	-1272	3740	-2217	3764	-2241	3768		33,000,000
58	North Branch	1	Wilston-Kuhl	1573	3075-3130	-1502	4000	-2427	4035	-2462	4040	1600	13,500,000
59	East Penn	1	J. A. Leslie	1893	3150-3220	-1257	4040	-2147	4085	-2192	4088	1650	40,000,000
60	Universal	1	H. A. Croft	1226	3130-3188	-1904	4065	-2839	4102	-2876	4138		
61	W. W. Keifer	1	Jud. Scofield	1445	4405	-2960	5475	-4030	5501	-4056	5548		
62	North Branch	1	Bertha House	1777	3720-3790	-1943	4693	-2916	4715	-2938	4666		
64	Penn-United	1	Geo. Boom	1696	3050-3120	-1354	4060	-2364	4082	-2386	4187		
65	North Branch	1	Geo. Barcroft	1609	2970-3035	-1361	3919	-2310	3944	-2335	3982	1600	6,000,000
66	Shaler Oil Co.	1	Leander Gee	1514	4612	-3098			(Estimated) 5636	-4122	5300		
67	Penn-United	1	Ida Russell	1646	3081-3140	-1435	3962	-2316	3984	-2338	4010½	1565	10,000,000
68	Lester & Miller	1	Wm. West	1065	4730-4800	-3665	5740	-4675	5762	-4697	5775		
69	Penn-United	1	Leander Gee	1812	3320-3380	-1508	4235	-2423	4254	-2442	4274	1575	4,250,000
70	Hultsinger	1	Earl Cummings	1606	4101	-2495	5016	-3410	5105	-3499	5110		
71	Midwest	1	Vine Hughes	1432	3610-3680	-2178	4810	-3378	4831	-3399	4853		

72	Taliaferro	1	H. G. Smith	1040	4209- 4293	-3169	5205	-4165	5231	-4191	5308		
73	North Branch	1	W. Middaugh	1673	3243- 3293	-1570	4597	-2924	4654	-2981	4672		
74	"	1	W. W. Colegrove	1610	2910- 2975	-1300	3928	-2318	3949	-2339	4004	1600	2,500,000
75	Lycoming	2	W. L. Herrington	1620	3066- 3130	-1446	4073	-2453	4093	-2473	4145		
76	Workman	1	Durfee Heirs	1439	3001- 3073	-1562	3954	-2515	3982	-2543	4019		
77	Penn-United	2	Ben Meaker	1702	3320- 3390	-1618			(estimated) 5070	-3368	5045		
78	Lycoming	2	Geo. Boom	1732	3053- 3100	-1321	4005	-2273	4029	-2297	4036	1650	4,500,000
79	Morris Run C.C.	1	W. J. Butters	1610	3835- 3950	-2225	5125	-3515	5215- 5275	-3605	5383		
80	East Penn	1	E. J. Hall	1763	3180- 3250	-1417	4100	-2337	4129	-2366	4142	1575	8,309,000
81	Allen Reed, Jr.	1	Leo Gee	1286	2992	-1706	3911	-2625	3942	-2656	3954		
82	C. E. Updegraf	1	C. E. Updegraf	1635	4290- 4385	-2655	5433	-3798	5490	-3855	5540		
83	Mutual Natural	1	Dana Learn	1649	3145- 3218	-1496	4067	-2418	4095	-2446	4108½	1600	11,776,635
84	Penn-United	1	Linus Wilston	1606	3100- 3175	-1494	4027	-2421	4051	-2445	4072	1570	4,000,000
85	Mutual Natural	1	Presbyterian Church	1845									
88	Workman et al	1	C. E. McCullum	1559	3153- 3213	-1594	4078	-2519	4103	-2544	4110		
90	East Penn	1	Chas. Thomas	1834	3157- 3222	-1323	4079	-2245	4110	-2276	4115		25,500,000
91	"	1	Jesse Smith	1836	3140- 3205	-1304	4189	-2353	4222	-2386	4233		6,000,000
92	Penn-United	1	Fred Fletcher	1723	3025- 3095	-1302	4023	-2300	4047	-2324	4061		3,000,000
93	"	2	Ida Russell	1696	3152- 3222	-1456	4071	-2375	4102	-2406	4128	1435	12,000,000
94	North Branch	1B	W. W. Colegrove	1395	2695- 2762	-1300	3651	-2256	3674	-2279	3696	1565	4,000,000
96	"	1											16,000,000

97	Gable et al	1	G. Burdette	1000	2325- 2393	-1325	3285	-2285	3305	-2305	3347		500,000
98	Mutual Natural	2	R. R. Murray	1291	2796- 2866	-1505	3727	-2436	3775	-2484	3787	1460	3,360,000
99	Lycoming	1	Myron Finch	1792	3314- 3385	-1522	4206	-2414	4223	-2431	4235		7,000,000
100	"	3	Farr-Colegrove	1680	3049- 3114	-1369	3986	-2306	4020	-2340	4027		32,000,000
101	Elkland Oil & Gas	1	Mrs. R. Van Duzen	1648	3550	-1902	4400	-2752	4418	-2770			
102	Tioga Nat.	1	Horace Cloos	1590	3100- 3180	-1510	4108	-2518	4140	-2550	4158		85,000
103	York Penn	1	Fred Preston	1510	3235- 3300	-1725	4190	-2680	4213	-2703	4220		
104	Penn-United	1	Lawrenceville Bank	1385	2890- 2950	-1505	3897	-2512	3923	-2538	3941	1530	2,250,000
105	Rodgers et al	1	N. E. French	1953	3650	-1697	4567	-2614	4577	-2624	4592		
106	Mellon-Pollock	2	C. H. Van Zile	1601	2883- 2941	-1282	3843	-2242	3870	-2269	3875	1440	25,000,000
107	Cowanesque Gas	1	J. N. Leonard	1480	2980	-1500	3847	-2367	3970	-2490	4030		
108	Penn-United	1	John Lacey	1677	4267- 4357	-2590	5254	-3577	5297- 5341	-3620	5347		
109	"	1	Geo. Stevens	1848	3401	-1553	4289	-2441	4305	-2457	4320	800	2,000,000
110	East Penn Dev.	1	T. T. Colegrove										

1. Abandoned 2-5-31 Salt water.
2. " " "
3. Completed 2-22-31.
4. " 2-21-31
5. Abd. no S.W. Top salt 4430
6. Completed 2-14-31
7. Abandoned 3-30-31 no salt water
8. " " "
9. " above sand
10. " no salt water
13. " 4-4-31 show gas shot 40 quarts.
14. Completed 11-8-31
15. Abandoned 3400' salt water
16. Completed 5-15-31
17. " July 1931
18. " 7-1-31
19. " 6-4-31
20. Abandoned 5-31-31; 2500' S.W.
21. " July 1931; no " "
22. " " " "
23. Completed " "
24. " 5-21-31
25. " 5-19-31
26. Completed 11-15-31
27. Abandoned Aug. 1931 no S.W.
28. " 10-1-32 " " "
29. " 6-20-31; 2730' S.W.
30. " 6-25-31; 3100' S.W.
31. " 8-13-31 no S.W.
32. Completed 6-9-31
33. " 7-14-31; shot 40 and 60 quarts
35. Abandoned Aug. 1931; show salt water and gas
36. Abandoned 7-30-31; no S.W.

37. Abandoned 6-16-32; no salt water
38. " 8- 6-31 " " "
39. " 11-12-31 " "
40. " 11- 5-31 " " "
41. " " " "
42. Completed September 1930
43. Abandoned no salt water; top salt 5200'
44. Completed 5-2-31
45. " 6-25-31
46. Abandoned 4-30-32; no salt water
47. Completed 5-25-31
48. Abandoned no salt water
49. " 5-31-32; no salt water show gas.
50. Abandoned 11-5-31; no salt water
51. " 9-3-31 above sand
52. " " "
53. Shut down 2880'
54. Abandoned 11-19-31; no salt water
55. " 9-12-31 above sand
56. Completed 9-9-31
58. " 9-5-31
59. " 9-3-31
60. Abandoned 3-5-32; no salt water
61. " 6-23-32 " " "
62. " 9-8-31 " " "
64. " 11-8-31 Show gas and salt water
65. Completed 10-1-31
66. Abandoned 1-28-32 above sand
67. Completed 9-30-31
68. Abandoned 6-30-32
69. Completed 11-3-31
70. Abandoned 12-23-31 no salt water
71. " 9-15-32 show salt water
72. " 1-28-32 no salt water
73. " 12-11-31 " " "
74. Completed 11-28-31
75. Abandoned 11-19-31 show gas and salt water
76. Abandoned 10-29-31 show gas, no salt water
77. Abandoned 2-6-31 above sand
78. Completed 12-17-31
79. Abandoned 2-25-32 no salt water or gas
80. Completed 1-13-32
81. Abandoned 2-18-32 salt water
82. " 8-4-32 no " " or gas
83. Completed 2-9-32
84. " 1-31-32
85. Shut down 1850
88. Abandoned 2-4-32 salt water 4109-10'
90. Completed 4-8-32
91. " 4-30-32
92. " 5-2-32
93. " 4-27-32
94. " 5-4-32
96. " 6-2-32
97. " 7-14-32
98. " 2-23-33
99. " 8-19-32
100. " 8-2-32
101. Salt water
102. " 12-20-32 - shot 40 and 50 quarts
103. Abandoned 2-15-33 salt water
104. Completed 11-2-32
105. Completed 6-8-33 2500' salt water in 24 hours
106. Completed 3-13-33
107. Abandoned 4-13-33, no salt water
108. Completed 11-16-33, no " "
109. " 1-24-34
110. Drilling 90, 2-9-34

ADJACENT PENNSYLVANIA

Map No.	County	Operator	Lessor	Sea level	Tully	Elev.	Onon-daga	Elev.	Orisk-any	Elev.	Total Depth	Rock Pres.	Open flow volume
110	Bradford	Moiserville Oil & Gas	Braested, S.G.	1635			4698	-3063	4729	-3094	4750		
111	"	Penn York	Hettick, G. R.	1280	3219	-1939	5133	-3853	5163	-3883	5227		
112	"	James Duff	Olsen, Geo.	1856	4394-4498	-2538	5585	-3729	5645	-3789	5681		
113	"	Penn-United	Bradford Co. Agr. school	740	3315-3425	-2575	5135	-4395			5307		
114	"	Mitchell, H.	Mitchell, H.	1140									
115	"	Scranton Water Co.	Morris, C. V.	925									
116	"	Penn York	Brown, P. M.	1260							6290		
117	"	York Penn	Dickinson	1245	4918	-3673					5450		
118	"	W. Keefer, Jr.	Kennedy	1445			5480	-4035	5510-5520	-4065	5530		
119	Susq.	Lk.o'Meadow Oil & Gas	Moore	1575									
120	Wyoming	Holt & Drum	Montrose	650									
121	Lycoming	C.H. Schrack et al	Myers	710							5080		
122	Potter	East Penn Dev. Co.	Emporium Lumb.Co.	1934	5523	-3589	6267	-4433	6280	-4346	6311		85,000
123	"	" " " "	" " #2	1647	5316-5365	-3669	6038	-4391	6043	-4396			
124	"	Atwater et al	Estes, G.	2170	4550-4610	-2780	5170	-3000	5197	-3027	5199	2110	13 mil.
125	"	Hammondsport Oil & Gas	Gale, W. L.	2211	4795	-2584	5695	-3484	5732	-3521	5744		
126	"	Potter Dev. Co.	Matteson	2180	4565-4617	-2385	5144	-2974	5160	-2980	5561		
127	"	" " "	Allen, W. H.	2217	4707-4870	-2490			5201	-2984	5356		
128	"	" " "	Stearns	2026			5106	-3080	5140	-3114	5247		
129	"	" " "	Gray Chem. Co.	2176	4799-4850	-2623	5380	-3204	5405	-3220	5488		
130	"	Cunningham et al	Moran, J.	2087	4288-4329	-2195	4836	-2749	4875	-2788	4879	1950	8 mil.

131	Potter	Ballis et al	Franke, L.	2250	5192	-2942	5829	-3579	5864	-3614	5881
132	"	Penna. Power & Light	Moe, F.	2405	4665	-2260	5297	-2892	5316- 5326	-2911	5440
133	Cameron	Tioga Natural Gas	Emporium Bank #1	1537							
134	"	" " "	" " #2	1654							
135	McKean	Atlantic Seaborad	Haywood Estate	1748	4755- 4794	-3007	5123- 5182	-3375	5182	-3434	5269
136	"	Derrick City	Brad. Deep Well Co.	1576					4135- 4155	-2559	5760
137	Elk	No. 3737	United Nat. Gas Co.	1836					5400	-3564	7930

110. Dry no salt water
111. " " " "
112. " " " "
113. Abandoned above Oriskany
114. Shut down at 4025'
115. " " " 4420'
116. Abandoned above Oriskany
117. " " "
118. Dry no salt water
119. Shut down at 4400'
120. Drilling ± 2600' 12-1-33
121. Abandoned above Oriskany
123. Gas drilling 6059' in Oriskany 2-9-34
125. Salt water

126. Dry, Oriskany sand absent
127. " " " "
128. Dry thin sand
129. Dry no Oriskany sand
130. Flowed salt water with gas
131. Dry, no Oriskany sandstone, cherty lime. Shut down at 5881'
132. Dry no salt water
133. Shut down 4480' 2-9-34
134. " " 4470' 2-9-34
135. Dry, no Oriskany sandstone
136. An old well, show of oil
137. Oriskany sand not present

NEW YORK

Map No.	County	Operator	Lessor	Sea level	Tully	Elev.	Onon-daga	Elev.	Orisk-any	Elev.	Total depth	Rock pres.	Open flow volume
138	Cattrugus.	Quinlin Oil Co.	J.B. Reed et al	1686	3740	-2054	4175	-2489	4276- 4295	-2590			
139	"	Ryder Scott	" " " " "	1877									
140	Chemung	Benedum & Trees	J. E. Murphy	1336	1890	- 554	3116	-1780	3175- 3194	-1839	3940		
141	"	Elmira Nat. Gas Co.	E. Berthald	913	2150	-1237	3275	-2362	3317	-2404	3433		
142	Steuben	Lyons et al	Monroe	1552	3692	-2140	4712	-3160	4736	-3184	4767		
143	"	Empire Keystone Co.	Lilly	1624	2865	-1241	3790	-2166	3826	-2202	3838		
144	Schuyler	J. D. Engle	J. D. Engle	1666			2820	-1154	2860	-1194	3004		
145	"	Tri-State O.&G. Co.	L. Webb	1675	1670		2664	- 989			2921		
146	Chemung	Peterman et al	Willis	1277	1976	- 699	3064	-1787	3118	-1841	3135		
147	"	Dearth, et al	Archie Turner	1110	1560	- 450	2805	-1695	2847	-1737	3085		
148	"	Brad-Tioga O.&G. Co.	R. Ingham	725	2220	-1495	3744	-3019	3776	-3051	3820		
149	Steuben	Peterman et al	Pealey	1046	2020	- 974	2865	-1819	2933	-1887	2945		
150	Tioga	Tioga Utilities Co.	B. Miller	979	2100	-1121			3390	-2411	3400		
151	Steuben	Perkins Peterman	Keith	1267	2448	-1181	3245	-1978	3268	-2001	3269		
152	"	Freeman & McIntyre	Porter	1902	3428	-1526	4093	-2191	4106	-2204	4135		
153	"	Wittmer Oil & Gas Co.	Broughton	1545	3270	-1725	3938	-2393	3993	-2448	4002		
154	"	" et al	Warner	2079	3882	-1803	4514	-2435	4550	-2471	4558	1545	1,000,000
155	"	"	Lewis Weber	1792	3554	-1762	4203	-2411	4256	-2464	4257		13,500,000

138. Show gas and oil
139. Drilling 4350' 2-9-34
140. Show gas - dry abandoned
141. Dry and abandoned
142. " " "
143. Salt water dry, abandoned
144. Dry
145. "
146. "

147. Dry
148. "
149. ", salt water
150. "
151. " " "
152. " salt water at 4135'
153. " " " " 4002'
154. Gas at 4552-55'

APPENDIX NO. 1

Oil in Tioga County

It has been indicated on preceding pages that, as judged from the relationship existing between the occurrence of petroleum and the volatile hydrocarbon content of coals in Pennsylvania, Tioga cannot be considered a favorable county in which to prospect for oil. Coal, where present, in Tioga County has a much lower volatile hydrocarbon content than do coals in the principal oil fields of the State, isovol values in Tioga County ranging between 20 and 37.5, whereas, in the principal oil field belt they generally exceed 40.

That the isovol values available to us are not infallible indices of the presence of oil is attested by the occurrence of a small commercial oil field at Gaines and by the presence of fair indications of oil in at least one other locality in the county. The Gaines Field is an exception to the rule. That exception can be satisfactorily explained, but the explanation does not exclude the possibility of another "Gaines" being found.

The point we make here is not that other oil fields cannot exist in this area, but merely that the chance of finding other commercial fields is so small that drilling for them cannot be considered a good prospecting venture.

Gaines Oil Field*

Gaines Field was discovered in 1897. It consisted of two pools, one of which extended from near Gaines to about a mile west of Watrous in a belt about 2 miles long and 600 to 800 feet wide; the other occupied a small oval area about half a mile in diameter just southwest of Manhattan. Figure 3.

The Watrous pool produced from a Chemung sand that lies about 700 feet below the lowest red bed of the Cattaraugus formation and is known as the Atwell sand. Early wells had initial production of up to 40 barrels a day, although most did not exceed 10 to 20 barrels. The average daily yield for the field was about 5 barrels.

The Manhattan pool did not produce from a specific sand but from a horizon about 200 feet above the Atwell sand that was called the Blossburg horizon. This horizon consists of an alternating series of shaly sandstones, shales, shaly limestones, and thin limestones. The oil apparently occurred along fissures and bedding planes, rather than in a definite sandstone. Many of the wells were of the gusher type, but were short-lived. Initial daily production varied from a few to 2,100 barrels.

Structurally the position of the Gaines Field is 2.7 miles south of the axis of the Pine Creek syncline and 2.5 miles north of the axis of the

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*Fuller, M. L., The Gaines Oil Field of Northern Pennsylvania, U.S. Geol. Sur., 22d Ann. Rept., Pt. 3, pp. 573-627, maps, 1902. Also U.S. Geol. Survey Folio No. 92.

Marshlands anticline. Dips in the field average about 3 degrees to the north; surface dips just north of the field are as high as 10 degrees. It is thought probable that oil accumulation here was induced chiefly by a terraced condition on the flank of the Marshlands anticline, the oil occurring just south of where the dip of the sand changed from about 3 to perhaps 10 degrees.

The average depth of the wells is 700 to 800 feet, with a minimum of about 600 feet and a maximum of about 1,000 feet. The Atwell sand is 11 to 24 feet thick, averaging about 18 feet. It thins toward the south and west and one mile east of Watrous is but 5 feet thick. Physically this sand resembled the Bradford sand. The oil is amber in color and has a gravity of 44° Baume. In general pressures were low; some wells flowed for a time but most had to be put on the pump soon after being drilled in. Commonly the wells were shot.

Surface waters usually were encountered only above 400 to 500 feet depth. The oil in the Watrous pool was free of water; that of the Manhattan pool commonly was mixed with salt water. Gas was not present in either pool in commercial amounts. In the Watrous pool it sufficed to run the boilers; in the Manhattan it was too small in amount to be used either as fuel or for illuminating purposes. In the "Blossburg formation" the gas commonly was intimately associated with the oil; in the Atwell sand gas tended to concentrate in the higher part of the reservoir.

Complete data are not available, but apparently something like 70 to 100 wells were drilled in the Watrous and 30 to 50 in the Manhattan pool. Some little oil is being produced in the Gaines Field today and occasionally there is talk of a resumption of drilling.

Fuller writing in 1901 remarks that --- the outlines of both pools appear to be rather definitely fixed by surrounding dry holes and the character of the wells along the producing belt itself --- salt water on the north and high gas content on the south. --- New wells sunk within the limits of the field meet with little success. --- It does not seem that the rocks occurring at a moderate depth beneath the Atwell or Blossburg horizons will produce oil in paying quantities as a number of wells have been drilled to 1,200 to 1,800 feet or more without encountering further oil. --- Oil may occur at great depth but the chances of finding it in quantity sufficient to compensate for deep drilling are not good. --- Sufficient drilling has been done about Gaines to indicate the improbability of the existence of any large (shallow) oil pool.

Thirty years have not appreciably changed the picture given by Fuller. As the Gaines Field is located on the flank of the Marshlands anticline near where the anticline plunges northeast and dies out, normal expectation would suggest that Gaines Field might continue in an arc following the plunge contour of the anticline. A limited amount of prospecting has not disclosed a continuation in that direction, and it is possible that oil accumulation here is confined to a distinctly localized terrace.

Wells have been drilled in most townships of Tioga County and some are reported to have encountered shows of oil without obtaining commercial production. While we do not believe that the chances for future discoveries will justify the cost of prospecting, it is not improbable that elsewhere small pools like the Gaines pool will be discovered eventually.